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Patient, physician and geographic predictors of cardiac stress testing strategy in Ontario, Canada: a population-based study

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ABSTRACT

Objectives To identify patient, physician and geographic level factors that are associated with variation in initial stress testing strategy in patients evaluated for chest pain.
Design Retrospective cohort study.
Setting Population-based study of patients undergoing evaluation for chest pain in Ontario, Canada between 1 January 2011 and 31 March 2018.
Participants 103 368 patients who underwent stress testing (graded exercise stress testing (GXT), stress echocardiography (stress echo) or myocardial perfusion imaging (MPI)) following evaluation for chest pain.
Primary and secondary outcome measures To identify the patient, physician and geographic level factors associated with variation in initial test selection, we fit two separate 2-level hierarchical multinomial logistic regression models for which the outcome was initial stress testing strategy (GXT, MPI or stress echo).
Results There was significant variability in the initial type of stress test performed, with approximately 50% receiving a GXT compared with approximately 36% who received MPI and 14% who received a stress echo. Physician-level factors were key drivers of this variation, accounting for up to 59.0% of the variation in initial testing. Physicians who graduated medical school >30 years ago were approximately 45% more likely to order an initial stress echo (OR 1.45, 95% CI 1.17 to 1.80) than a GXT. Cardiovascular disease specialists were approximately sevenfold more likely to order an initial MPI (OR 7.35, 95% CI 5.38 to 10.03) than a GXT. Patients aged >70 years were approximately fivefold more likely to receive an MPI (OR 4.74, 95% CI 4.42 to 5.08) and approximately 26% more likely to receive a stress echo (OR 1.26, 95% CI 1.15 to 1.38) than a GXT.
Conclusions We report significant variability in initial stress testing strategy in Ontario. Much of that variability was driven by physician-level factors that could potentially be addressed through educational campaigns geared at reducing this variability and improving guideline adherence.

Strengths and limitations of this study

- ► This is a large, population-level study with data from 103 368 patients who received stress testing after evaluation for chest pain in Ontario, Canada.
- ► Given Ontario and Canada's single payer government funded healthcare system, we were able to extract patient information with virtually 100% coverage of the population of Ontario.
- ► We were unable to evaluate coronary computed tomography angiography (CTA) as an initial testing strategy due to the very low numbers of initial CTA tests performed in Ontario.
- ► This is an observational study, and as such, we were unable to account for unmeasurable and/or unknown patient, physician and geographic confounders.

INTRODUCTION

Despite recent advances in care, coronary artery disease (CAD) remains a major public health problem. The 2010 American Heart Association Heart Disease and Stroke Statistics Update reported that there were approximately 18 million people in the USA who had been diagnosed with CAD.[1] CAD is the second leading cause of death in the USA and Canada and is responsible for approximately 30% of all deaths worldwide.[2–4] CAD is also a high cost condition.[5 6] The economic impact of CAD is considerable, with annual costs of approximately $220 billion in the USA.[7] As an extension, diagnostic stress testing for CAD is prevalent and expensive. Commonly available technologies include the graded exercise stress test (GXT) as well as stress imaging tests, such as myocardial perfusion imaging (MPI) and stress echocardiography (stress echo). Prior work from our group has reported that approximately 500 000 GXTs, MPIs or stress echocardiograms are performed annually in Ontario, Canada[8] with direct costs of approximately $300 million/year. High utilisation rates and costs have led to scrutiny by researchers and policymakers with concerns of overuse.[9–14] Despite North American guideline recommendations that the least expensive and most widely available modality, the GXT, be ordered as the first line stress test in the work-up of patients for CAD,[4 15] our prior work indicates that significant variations exist in the initial non-invasive diagnostic testing strategy in Ontario.[8]

Understanding the drivers of such variations in practice patterns are important for policymakers as they may direct one to the genesis of system inefficiencies and areas for improvement.[16–20] The objective of this study was to elucidate the patient, physician and geographic level predictors of variation in initial non-invasive cardiac diagnostic testing strategy in Ontario, Canada.

METHODS

The dataset from this study is held securely in coded form at ICES (formerly known as the Institute for Clinical Evaluative Sciences). While data sharing agreements prohibit ICES from making the dataset publicly available, access may be granted to those who meet prespecified criteria for confidential access, available at wwwicesonca/DAS. The full dataset creation plan and underlying analytic code are available from the authors on request, understanding that the computer programs may rely on coding templates or macros that are unique to ICES and are therefore either inaccessible or may require modification. ICES is an independent, non-profit research institute funded by an annual grant from the Ontario Ministry of Health and Long-Term Care. As a prescribed entity under Ontario's privacy legislation, ICES is authorised to collect and use healthcare data for the purposes of health system analysis, evaluation and decision support. Secure access to these data is governed by policies and procedures that are approved by the Information and Privacy Commissioner of Ontario. The use of the data in this project is authorised under section 45 of Ontario's Personal Health Information Protection Act (PHIPA) after review by ICES' Privacy and Legal Office.

DESIGN

We conducted a retrospective cohort study of patients undergoing evaluation for chest pain in Ontario, Canada between 1 January 2011 and 31 March 2018.

DERIVATION OF THE COHORT

Inclusion criteria included age ≥20 years and evaluation by one of 4000 randomly selected physicians in Ontario for chest pain with one of three available stress testing modalities: GXT, MPI or stress echo. A random sample of 4000 physicians was chosen from the population of 18 718 physicians in Ontario, as the subsequent regression models could not be fit in the full sample. The 4000 physicians were randomly selected from a pool of all active physicians in Ontario and were not restricted to any subspecialty group. We used simple random sampling method with a fixed random number seed to select 4000 referring physicians, and linked them to the original study cohort. Patients must have received one of an MPI, stress echo or GXT to be included in the cohort. We excluded patients with a previous diagnosis of CAD in order to construct an inception cohort by excluding those with a history of cardiovascular disease in the preceding 20 years using a previously validated algorithm that has been used in prior work.[5 6 17 21 22] Furthermore, we implemented a 1 year washout period whereby those who had a stress test in the year prior to evaluate for chest pain were excluded.

DATA SOURCES

Patient evaluation for chest pain as well as receipt of stress testing was ascertained by the Ontario Health Insurance Plan (OHIP) Physician Claims Database. The OHIP Physician Claims Database is the most frequently used ICES database and has been validated by multiple studies in many disease states.[8 21 23–27] The Registered Persons Database, a registry of Ontario residents who are registered for Ontario Health insurance coverage, was used to obtain demographic information. The presence of diabetes and hypertension were determined through the Ontario Diabetes and Ontario Hypertension databases, respectively. History of chronic obstructive pulmonary disease (COPD) and cancer were determined via the Ontario COPD and Ontario Cancer Registry, respectively.

DATABASE VALIDATION AND ADDITIONAL DATA DICTIONARY INFORMATION

The above-mentioned databases are commonly used by Ontario's health services and clinical researchers and have been validated in a variety of clinical settings including CAD and heart failure.[28–40] Data dictionaries for the above listed databases can be accessed online (https://wwwicesonca/Data-and-Privacy/ICES-data/Data-dictionary).

DATA EXTRACTION, LINKAGE AND QUALITY CONTROL

The first step when ICES collects data is the removal of direct personal identifiers and the assignment of a confidential unique encoded identifier, also known as the IKN, to each record. An IKN exists for every Ontario resident who has been eligible for healthcare over time. This identifier is created using a secure ICES algorithm that is based on the Ontario health card number. Once records in a data set have an IKN assigned, the directly identifying information is stripped off the file and the data become part of the ICES data inventory—uniquely coded and linkable across health services data bases within the inventory. The above listed databases (detailed in the Data sources section) were linked using these unique encoded identifiers (IKNs) in order to obtain the dataset for this study. Given Ontario and Canada's single payer government funded healthcare system, we were able to extract patient information with virtually 100% coverage of the population of Ontario.

Database linkage and subsequent data extraction from the linked ICES databases was performed by an ICES statistical analyst not affiliated with the primary investigator of the study. ICES statistical analysts have expertise in conducting statistical analysis with linked health administrative data, including both basic descriptive and complex modelling statistics as well as in highly complex methods commonly used with observational data. All data and analytic services are conducted while adhering to the strict requirements of the Office of the Information and the Privacy Commissioner of Ontario. This includes appropriate logging and reporting of study plans, conduct and deliverables while ensuring security of the ICES data holdings.

In addition, all statistical analysis plan and analyses are overseen by an independent statistical methodologist to ensure the accuracy and validity of the data extraction, linkage and statistical analyses.

STATISTICAL ANALYSIS

In order to understand the patient, physician and geographic level factors affecting variation in initial test selection, we fit two separate 2-level hierarchical multinomial logistic regression model for which the outcome was initial stress testing strategy (GXT, MPI or stress echo). The levels of the data structure were patient, physician and geographic (subregions in Ontario). Ontario's 76 subregions are government mandated, local planning regions that serve as the focal point for improved health system planning, performance improvement and service integration. They are the avenue for local improvement and innovation with the common objective of improving the patient experience.

The reference category for the multinomial outcome was GXT. Multilevel or hierarchical models allow one to incorporate between-physician and between-subregion variation in test selection.[41–44] Due to the size of the sample and the complexity of the model, we were unable to fit a 3-level hierarchical model. Therefore, we fit two 2-level hierarchical models as opposed to a single, 3-level model. The first model (the physician model) accounted for clustering of patients within the 4000 referring physician by incorporating physician-specific random effects while adjusting for patient and physician variables as fixed effects. Geographic level variables were not included in this model. The physician specific random effects were based on the physician referring for the testing. In Ontario, the physician referring a patient for the stress test determines which test is performed. Therefore, the physician specific variables were based on the referring physician's characteristics. The second model (the geographic model) accounted for clustering of patients within the subregions in Ontario by incorporating subregion-specific random effects while adjusting for patient and subregion variables as fixed effects. Physician level variables were not included in this model. The candidate variables/predictors were selected a priori on the basis of clinical importance.[5 17 18 45–47]

Patient level factors

Demographics (age, sex), clinical characteristics (cardiac risk factors, medical comorbidities), income quintile (based on median neighbourhood income), rural versus urban location of residence, year of test, distance to referring physicians' office (derived distance in kilometres between the physician's and patient's postal code (Canadian version of a ZIP code)).

Physician level factors

Sex, years since medical school graduation, specialty of the referring physician.

Geographic level factors (by subregion)

Physician density (physicians/100 000 population) and density of cardiovascular disease specialists (cardiovascular disease specialists/100 000 population).

We computed variance partition coefficients for each multilevel multinomial logistic regression models using the between-cluster variance divided by the sum of the between-subject variance and the between-cluster variance. These variance partition coefficients were calculated to determine the proportion of the observed variation in the outcome that could be attributable to between-cluster differences.[48] All analyses were conducted using SAS V.9.4 (SAS Institute). Statistical tests were two-sided, with a significance level of 0.05.

Patient and public involvement

No patient involved.

RESULTS

Derivation of the patient population

507 995 patients had a stress test in Ontario during our study period. Of these, 3655 patients were excluded due to incomplete information regarding the location of their tests. We then evaluated the tests performed by a randomly selected cohort of 4000 physicians. This resulted in the final cohort of 1 03 368 patients (see figure 1).

Initial testing strategy

51 210 patients (49.5%) had an initial GXT while 37 126 patients (35.9%) had an initial MPI and 15 032 patients (14.5%) had an initial stress echo.

Baseline patient, physician and geographic characteristics

Baseline patient characteristics are reported in table 1. Overall, the mean age of the cohort was 57.7±13.0 years with patients undergoing initial testing with MPI being significantly older than those undergoing initial stress echo or GXT (p<0.0001). Patients undergoing initial testing with MPI were also more likely to be female, have a history of cancer or COPD and have major cardiovascular risk factors such as diabetes, hypertension

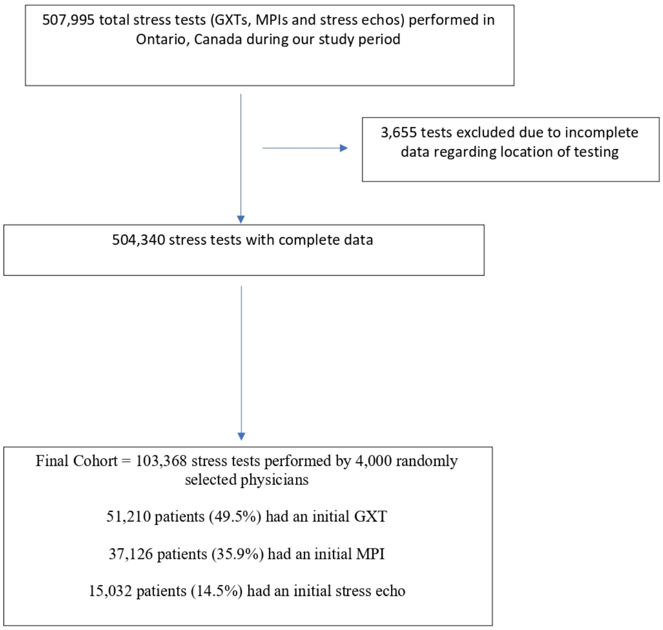

Figure 1 Derivation of the patient population. GXT, graded exercise stress test; MPI, myocardial perfusion imaging; stress echo, stress echocardiography.

and dyslipidaemia (p<0.0001 for all). Patients in rural locations were more likely to have a GXT performed compared with patients from urban locations. Those in higher-income neighbourhood were slightly more likely to receive GXT versus MPI or stress echo. 42.1% of GXTs were performed in the top two income quintiles versus 38.8% of MPIs and 41.7% of stress echos (p<0.0001).

Variability in initial testing strategy

The proportion of physician variation is reported from a 2-level model, and therefore reflects the variance explained by physician factors in a model containing patient factors. Similarly, the proportion of geographic variability is also reported from a 2-level model and evaluates the variance due to geographic factors in relation to patient factors. Using data from those two separate 2-level models, we report the following results: for MPI (vs GXT), 18.8% of the variation in initial testing strategy in our cohort could be explained by between-subregion (geographic) factors and 54.0% of the variation could be explained by between-physician factors. For stress echo (vs GXT), 20.1% of the variation could be explained by between-geographic factors and 59.0% could be explained by between-physician level factors (see online supplemental table S1).

Independent predictors of initial testing strategy

Tables 2 and 3 report the ORs and 95% CI of the independent patient, physician and geographic level predictors of initial stress testing strategy from our two models, after adjustment for covariates.

Patient level factors

Since the point estimates were very similar for our two models and the majority of variability was attributable to between-physician differences, we chose to report key ORs and 95% CIs for patient-level factors from the 'physician model' in the text of this paper. MPI was increasingly more likely to be the first test performed as patient age increased, when compared with GXT. Those patients >70 years old were approximately fivefold more likely to have an MPI as their initial test versus GXT compared with those who were ≤70 years old. These older patients were also approximately 26% more likely to have an initial stress echo versus an initial GXT compared with younger patients. Males were approximately 20% less likely to get initial MPIs (OR 0.80, 95% CI 0.77 to 0.83) or stress echos (0.78, 95% CI 0.74 to 0.82) than an initial GXT compared with females. Patients with comorbidities (eg, those with a history of cancer, COPD or diabetes) were significantly more likely to receive MPI than GXT compared with those without comorbidities (p<0.0001). Those living in neighbourhoods in the highest income quintile were significantly less likely to get an initial MPI versus an initial GXT (OR 0.80, 95% CI 0.75 to 0.85) but similarly likely to have an initial stress echo (OR 0.97, 95% CI 0.89 to 1.05) compared with those in the lowest income quintile. Patients in a later period were significantly more likely to receive an initial stress echo (OR 1.27, 95% CI 1.25 to 1.30) and significantly less likely to receive an initial MPI (0.96, 95% CI 0.94 to 0.98) than an initial GXT compared with patients in earlier periods.

Physician level factors

Male physicians were approximately 40% less likely to order an initial stress echo versus an initial GXT (OR 0.61, 95% CI 0.50 to 0.75) compared with female physicians. Cardiovascular diseases specialists were approximately sevenfold more likely to order an initial MPI and approximately threefold more likely to order an initial stress echo compared with non-cardiovascular diseases specialists. Older physicians, specifically those who graduated medical school >30 years ago, were approximately 45% more likely to order a stress echo (OR 1.45, 95% CI 1.17 to 1.80) compared with those who graduated more recently.

Geographic level factors

Physician density/100 000 population was not significantly associated with initial MPI or stress echo testing. However, a higher number of cardiovascular diseases specialists/100 000 population was associated with significantly higher initial use of stress echo compared with use of GXT. In the highest stratum, in regions with >10 cardiovascular diseases specialists/100 000 population, patients were more than 2.5-fold more likely to have an initial stress echo versus an initial GXT (OR 2.66, 95% CI 1.15 to 6.13).

DISCUSSION

Our population-based study indicates significant variability in the initial choice of stress testing modality in Ontario,

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Table 1 Characteristics of the patient population

		GXT	MPI	Stress echo	Total	P value
		n=51 210	n=37 126	n=15 032	n=103 368	
Patient-level factors						
Year of test	2010, n (%)	3045 (5.9%)	2552 (6.9%)	0 (0.0%)	5597 (5.4%)	<0.0001
	2011, n (%)	8593 (16.8%)	7906 (21.3%)	740 (4.9%)	17 239 (16.7%)	
	2012, n (%)	7132 (13.9%)	5965 (16.1%)	1658 (11.0%)	14 755 (14.3%)	
	2013, n (%)	7814 (15.3%)	4934 (13.3%)	2423 (16.1%)	15 171 (14.7%)	
	2014, n (%)	6982 (13.6%)	4426 (11.9%)	2301 (15.3%)	13 709 (13.3%)	
	2015, n (%)	6291 (12.3%)	3923 (10.6%)	2388 (15.9%)	12 602 (12.2%)	
	2016, n (%)	5911 (11.5%)	3834 (10.3%)	2648 (17.6%)	12 393 (12.0%)	
	2017, n (%)	5442 (10.6%)	3586 (9.7%)	2874 (19.1%)	11 902 (11.5%)	
Age (years)	Mean (SD)	54.7 (12.6)	62.6 (12.3)	56.3 (12.7)	57.7 (13.0)	<0.0001
Sex	Females, n (%)	24 443 (47.7%)	19 620 (52.8%)	7878 (52.4%)	51 941 (50.2%)	<0.0001
	Males, n (%)	26 767 (52.3%)	17 506 (47.2%)	7154 (47.6%)	51 427 (49.8%)	
COPD	n (%)	1336 (2.6%)	2166 (5.8%)	473 (3.1%)	3975 (3.8%)	<0.0001
Diabetes	n (%)	5689 (11.1%)	8419 (22.7%)	2073 (13.8%)	16 181 (15.7%)	<0.0001
Hypertension	n (%)	13 655 (26.7%)	12 832 (34.6%)	4371 (29.1%)	30 858 (29.9%)	<0.0001
Dyslipidaemia	n (%)	19 502 (38.1%)	21 725 (58.5%)	6168 (41.0%)	47 395 (45.9%)	<0.0001
Cancer	n (%)	2980 (5.8%)	4296 (11.6%)	1013 (6.7%)	8289 (8.0%)	<0.0001
Distance between patient residence and referring physician office (km)	Median (Q1–Q3)	6.5 (2.9–15.9)	7.3 (3.3–18.1)	8.1 (3.4–19.1)	7.0 (3.1–17.1)	<0.0001
Distance categorised by group (km)	0.0–5.0, n (%)	21 381 (41.8%)	14 112 (38.0%)	5354 (35.6%)	40 847 (39.5%)	<0.0001
	5.1–10.0, n (%)	10 909 (21.3%)	7994 (21.5%)	3201 (21.3%)	22 104 (21.4%)	
	10.1–20.0, n (%)	9001 (17.6%)	6568 (17.7%)	2894 (19.3%)	18 463 (17.9%)	
	20.1+, n (%)	9919 (19.4%)	8452 (22.8%)	3583 (23.8%)	21 954 (21.2%)	
Rural location	n (%)	4830 (9.4%)	3044 (8.2%)	1181 (7.9%)	9055 (8.8%)	<0.0001
Neighbourhood income quintile	1 (lowest), n (%)	8716 (17.0%)	7370 (19.9%)	2713 (18.0%)	18 799 (18.2%)	<0.0001
	2, n (%)	10 291 (20.1%)	7946 (21.4%)	2972 (19.8%)	21 209 (20.5%)	
	3, n (%)	10 643 (20.8%)	7622 (20.5%)	3070 (20.4%)	21 335 (20.6%)	
	4, n (%)	10 892 (21.3%)	7222 (19.5%)	3160 (21.0%)	21 274 (20.6%)	
	5 (highest), n (%)	10 668 (20.8%)	6966 (18.8%)	3117 (20.7%)	20 751 (20.1%)	
Geographic-level factors						
Physicians per 100 000 population	Mean (SD)	140.6 (46.9)	144.7 (53.3)	141.6 (54.6)	142.2 (50.5)	<0.0001
	62–100, n (%)	8978 (17.5%)	6093 (16.4%)	3568 (23.7%)	18 639 (18.0%)	<0.0001
	101–130, n (%)	15 063 (29.4%)	13 086 (35.2%)	4908 (32.7%)	33 057 (32.0%)	
	131–160, n (%)	17 093 (33.4%)	9300 (25.0%)	3174 (21.1%)	29 567 (28.6%)	
	161+, n (%)	10 076 (19.7%)	8647 (23.3%)	3382 (22.5%)	22 105 (21.4%)	
Cardiovascular disease specialists per 100 000 population	Mean (SD)	7.2 (7.2)	8.2 (7.9)	8.3 (7.6)	7.7 (7.5)	<0.0001
	0–3.0, n (%)	12 620 (24.6%)	7152 (19.3%)	2232 (14.8%)	22 004 (21.3%)	

Continued

Table 1 Continued

		GXT	MPI	Stress echo	Total	P value
	3.1–5.0, n (%)	13 699 (26.8%)	9444 (25.4%)	3412 (22.7%)	26 555 (25.7%)	
	5.1–10.0, n (%)	14 595 (28.5%)	12 000 (32.3%)	6189 (41.2%)	32 784 (31.7%)	
	10.1+, n (%)	10 296 (20.1%)	8530 (23.0%)	3199 (21.3%)	22 025 (21.3%)	
Physician-level factors						
Referring physician specialty						<0.0001
	Cardiovascular diseases, n (%)	7690 (15.0%)	17 294 (46.6%)	4235 (28. 2%)	29 219 (28.3%)	
	Family physician, n (%)	35 140 (68.6%)	12 729 (34.3%)	9215 (61.3%)	57 084 (55.2%)	
	Internal medicine, n (%)	4451 (8.7%)	3787 (10.2%)	799 (5.3%)	9037 (8.7%)	
	Others, n (%)	3929 (7.7%)	3316 (8.9%)	783 (5.2%)	8028 (7.8%)	
Years since graduation from medical school	Mean (SD)	25.2 (11.6)	26.7 (11.6)	25.6 (11.9)	25.8 (11.7)	<0.0001
	1–10, n (%)	7360 (14.4%)	3644 (9.8%)	1968 (13.1%)	12 972 (12.5%)	<0.0001
	11–20, n (%)	10 537 (20.6%)	8172 (22.0%)	3429 (22.8%)	22 138 (21.4%)	
	21–30, n (%)	14 316 (28.0%)	10 283 (27.7%)	3917 (26.1%)	28 516 (27.6%)	
	31+, n (%)	18 997 (37.1%)	15 027 (40.5%)	5718 (38.0%)	39 742 (38.4%)	

COPD, chronic obstructive pulmonary disease; GXT, graded exercise stress test; MPI, myocardial perfusion imaging; stress echo, stress echocardiography.

Canada with approximately 50% of patients receiving a GXT as the first line test compared with approximately 36% who had a first line MPI and 14% who had a first line stress echo. Physician-level factors were key drivers of this variation, with between-physician differences accounting for up to 59% of the variation in initial testing strategy. Between-region differences accounted for a much smaller proportion of the variation, up to 20.1%. Key physician-level independent predictors of initial evaluation with stress imaging (compared with GXT) include referral for testing by a cardiologist, and a greater number of years since graduation from medical school. Key patient-level independent predictors of initial assessment with stress imaging include older age, female sex and co-morbidities such as cancer and COPD. Patients from higher income regions were less likely to undergo initial testing with an MPI but not more likely to undergo initial testing with stress imaging when compared with those of lower income levels.

There is a discrepancy between European and North American cardiology guidelines with regards to their respective recommendations for initial stress testing strategies. The European Society of Cardiology recommends initial stress imaging while American and Canadian guidelines recommend GXT as the first line test in the evaluation of stable CAD.[4 49] Regardless of the guideline recommendations, real-world practice variations exist that do not reflect adherence to these recommendations.

In prior work, our group evaluated the initial diagnostic strategy in patients undergoing evaluation for chest pain in Ontario, Canada between 2012 and 2013. We reported that GXT was the initial test of choice in only approximately 42% of patients, despite Canadian guideline recommendations that strongly recommend GXT as the first line test for CAD.[24] American data have also reported significant variability in initial testing patterns with an even greater use of initial stress imaging despite similar recommendations.[50] Consistent with this prior work, data presented in the current paper report significant variability in initial testing strategy, with only approximately 50% of patients receiving a first line GXT.

Practice variation is an important target for healthcare system improvement. Some degree of variation in care is justified, and may be driven to some extent by patient case-mix. However, variation that is not due to patient risk factors or preferences is common and can lead to inappropriate utilisation, inefficient care and increased costs.[51–53] In an effort to shed more light on to the drivers of variation in non-invasive cardiac testing in Ontario, we used hierarchical regression models in order to explore patient, physician and geographic predictors of the initial testing strategy. In our study, the strongest predictors of initial testing strategy were physician related. In fact, between-physician differences accounted for the majority in the observed variability in initial testing strategy. Cardiovascular diseases physicians contributed to this

Table 2 ORs and 95% CIs of patient and physician level determinants of initial stress testing strategy

Variable	Modality (vs GXT)	Adjusted OR	Lower 95% CI	Upper 95% CI	P value
Patient-level factors					
Year of test					
	MPI	0.96	0.94	0.98	0.0004
	Stress echo	1.27	1.25	1.30	<0.0001
Age group (years)					
51–60	MPI	1.92	1.82	2.03	<0.0001
61–70	MPI	2.70	2.54	2.87	<0.0001
70+	MPI	4.74	4.42	5.08	<0.0001
51–60	Stress echo	1.10	1.03	1.18	0.003
61–70	Stress echo	1.20	1.12	1.30	<0.0001
70+	Stress echo	1.26	1.15	1.38	<0.0001
Distance from physician (km)					
5.1–10	MPI	1.08	1.02	1.14	0.008
10.1–20	MPI	1.08	1.01	1.14	0.016
20.1+	MPI	1.14	1.07	1.21	<0.0001
5.1–10	Stress echo	1.02	0.95	1.10	0.52
10.1–20	Stress echo	1.02	0.94	1.10	0.66
20.1+	Stress echo	1.00	0.93	1.08	0.96
Male sex					
	MPI	0.80	0.77	0.83	<0.0001
	Stress echo	0.78	0.74	0.82	<0.0001
History of cancer					
	MPI	1.38	1.28	1.48	<0.0001
	Stress echo	1.09	0.99	1.21	0.081
COPD	MPI	1.58	1.42	1.76	<0.0001
	Stress echo	1.23	1.07	1.42	0.0048
Diabetes mellitus	MPI	1.70	1.61	1.80	<0.0001
	Stress echo	1.15	1.07	1.24	0.0003
Dyslipidaemia	MPI	1.02	0.97	1.06	0.51
	Stress echo	1.02	0.97	1.09	0.41
Rural location	MPI	1.27	1.14	1.40	<0.0001
	Stress echo	1.03	0.91	1.16	0.67
Neighbourhood income quintile (vs quintile 1, lowest)					
2	MPI	0.94	0.88	1.00	0.047
3	MPI	0.89	0.83	0.95	0.0003
4	MPI	0.84	0.79	0.90	<0.0001
5	MPI	0.80	0.75	0.85	<0.0001
2	Stress echo	0.98	0.90	1.06	0.65
3	Stress echo	0.98	0.91	1.07	0.69
4	Stress echo	1.02	0.94	1.11	0.65
5	Stress echo	0.97	0.89	1.05	0.47
Physician-level factors					

Continued

Table 2 Continued

Variable	Modality (vs GXT)	Adjusted OR	Lower 95% CI	Upper 95% CI	P value
Referring physician specialty					
Cardiovascular diseases	MPI	7.35	5.38	10.03	<0.001
Family practice	MPI	0.12	0.09	0.14	<0.001
Internal medicine	MPI	2.48	1.73	3.55	<0.001
Cardiovascular diseases	Stress echo	2.80	1.97	3.99	<0.001
Family practice	Stress echo	1.10	0.85	1.43	0.46
Internal medicine	Stress echo	1.00	0.61	1.64	0.99
Years since graduation from medical school					
11–20	MPI	1.26	1.10	1.43	<0.001
21–30	MPI	1.33	1.14	1.55	<0.001
>30	MPI	1.15	0.96	1.39	0.122
11–20	Stress echo	1.02	0.87	1.20	0.80
21–30	Stress echo	0.98	0.81	1.18	0.83
>30	Stress echo	1.45	1.17	1.80	<0.001
Male sex of the referring physician					
	MPI	0.99	0.84	1.18	0.94
	Stress echo	0.61	0.50	0.75	<0.0001

COPD, chronic obstructive pulmonary disease; GXT, graded exercise stress test; MPI, myocardial perfusion imaging; stress echo, stress echocardiography.

variability as they were significantly more likely to order initial testing with an MPI or stress echo as opposed to a GXT. This finding appear to be counterintuitive, given that one would anticipate subspecialists are more aware of recommended practice. Understanding these practice patterns in more detail is important, specifically if financial remuneration and gain are playing a role. There is some data available indicating that financial interest may indeed play a significant role in the type of stress test performed. For example, a large population-based study from the USA reported that MPI and stress echocardiography were more frequently performed among patients treated by physicians who billed for the respective technical and/or professional fees when compared with those treated by physicians who did not bill for these services.[54] Given that physician driven factors were found to be key determinants of the type of initial test performed in our study, providing effective educational support for these physicians may potentially lead to more uniform practice and greater adherence to guideline recommendations.

An additional interesting finding of our paper was that neighbourhood income level of where patients reside was not significantly associated with receipt of more expensive tests, namely stress echo or MPI. Patients residing in Ontario's highest income neighbourhoods did not have significantly higher utilisation of stress imaging as an initial testing strategy. This finding is in contrast to work from other jurisdictions including the USA which reported that neighbourhood income was linked to more expensive cardiac diagnostic testing options.[55 56] The most likely explanation for this discrepancy may lie in Canada's universal, single-payer, healthcare system where decisions for testing are not impacted by the ability to pay.

LIMITATIONS

Our paper must be interpreted in the context of its limitations. First, we were unable to evaluate coronary computed tomography angiography (CTA) as an initial testing strategy due to the very low numbers of initial CTA tests performed and subsequent difficulties in integrating it into our multi-level, multinomial logistic regression model. In fact, <0.5% of patients in Ontario received CTA as their initial testing strategy. Given this small number, it is unlikely that we could have derived useful conclusions regarding the predictors of CTA as an initial test choice even if the modality was included in the outcome measure. Second, our databases lacked granularity in certain domains, especially information on disability/infirmity, the ability to exercise and the presence of baseline ECG abnormalities, each of which could impact choice of initial testing. However, we did include variables in our models which are associated with higher disability/infirmity such as COPD, cancer and cardiovascular risk factors. Third, due the size of the sample and the complexity of the model, we were unable to fit a 3-level

Table 3 ORs and 95% CIs of patient and geographic level determinants of initial stress testing strategy

Variable	Modality (vs GXT)	Adjusted OR	Lower 95% CI	Upper 95% CI	P value
Patient-level factors					
Year of test					
	MPI	0.94	0.94	0.95	<0.001
	Stress echo	1.27	1.26	1.29	<0.001
Age group (years)					
51–60	MPI	1.83	1.76	1.91	<0.001
61–70	MPI	2.56	2.45	2.68	<0.001
70+	MPI	4.34	4.12	4.56	<0.001
51–60	Stress echo	1.07	1.02	1.13	0.009
61–70	Stress echo	1.14	1.08	1.21	<0.001
70+	Stress echo	1.23	1.15	1.32	<0.001
Distance from physician (km)					
5.1–10	MPI	1.15	1.11	1.20	<0.001
10.1–20	MPI	1.24	1.19	1.29	<0.001
20.1+	MPI	1.54	1.47	1.60	<0.001
5.1–10	Stress echo	1.09	1.04	1.15	0.001
10.1–20	Stress echo	1.17	1.10	1.23	<0.001
20.1+	Stress echo	1.31	1.24	1.39	<0.001
Male sex	MPI	0.84	0.82	0.87	<0.001
	Stress echo	0.80	0.77	0.84	<0.001
History of cancer	MPI	1.46	1.38	1.54	<0.001
	Stress echo	1.04	0.96	1.13	0.359
COPD	MPI	1.66	1.53	1.79	<0.001
	Stress echo	1.15	1.03	1.30	0.017
Diabetes mellitus	MPI	1.73	1.66	1.80	<0.001
	Stress echo	1.18	1.11	1.25	<0.001
Dyslipidaemia	MPI	1.00	0.97	1.04	0.96
	Stress echo	1.04	0.99	1.08	0.12
Rural location	MPI	1.27	1.14	1.40	<0.001
	Stress echo	1.03	0.91	1.16	0.67
Neighbourhood income quintile (vs quintile 1, lowest)					
2	MPI	0.94	0.88	0.99	0.047
3	MPI	0.89	0.83	0.95	<0.001
4	MPI	0.84	0.79	0.90	<0.001
5	MPI	0.80	0.75	0.86	<0.001
2	Stress echo	0.98	0.90	1.07	0.65
3	Stress echo	0.98	0.91	1.07	0.69
4	Stress echo	1.02	0.94	1.11	0.65
5	Stress echo	0.97	0.89	1.06	0.47
Geographic-level factors					
Physician density per 100 000 population					
101–130	MPI	1.27	0.73	2.20	0.40
131–160	MPI	0.63	0.35	1.14	0.13

Continued

Table 3 Continued

Variable	Modality (vs GXT)	Adjusted OR	Lower 95% CI	Upper 95% CI	P value
161+	MPI	0.95	0.48	1.90	0.89
101–130	Stress echo	0.67	0.37	1.22	0.192
131–160	Stress echo	0.31	0.16	0.59	<0.001
161+	Stress echo	0.51	0.24	1.09	0.083
Cardiovascular disease specialists per 100 000 population					
3.1–5.0	MPI	1.22	0.71	2.11	0.47
5.1–10.0	MPI	1.57	0.91	2.73	0.11
10.1+	MPI	1.70	0.78	3.71	0.18
3.1–5.0	Stress echo	1.57	0.88	2.82	0.13
5.1–10.0	Stress echo	2.89	1.60	5.20	<0.001
10.1+	Stress echo	2.66	1.15	6.13	0.022

COPD, chronic obstructive pulmonary disease; GXT, graded exercise stress test; MPI, myocardial perfusion imaging; stress echo, stress echocardiography.

hierarchical model. Instead, we fit two 2-level hierarchical models as opposed to a single, 3-level model. Finally, ours is an observational study and as such, we were unable to account for unmeasurable and/or unknown patient, physician and geographic confounders. The observational and retrospective nature of the study also allows for the possibilities that there were patients who met criteria for stress testing but never underwent it, and that physicians may have preferentially ordered testing in certain subgroups.

CONCLUSIONS

Our population-based study of approximately 100 000 patients in Ontario, Canada reports that there was significant variability in initial stress testing strategy in Ontario, Canada. Much of that variability was driven by between-physician differences that could potentially be addressed through educational campaigns geared at reducing this variability and improving guideline adherence. Unlike other specialties, cardiovascular diseases physicians were significantly more likely to order both initial MPIs and stress echos rather than GXTs.

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Ethics approval This study involves human participants but This project was reviewed by ICES Privacy and Legal Office (TRIM # 2020-0990-243-000) and does not require review by a Research Ethics Board nor does it require patient informed consent. Under Ontario legislation (PHIPA), studies are approved by ICES' Privacy and Legal Office in-lieu of a hospital-based Research Ethics Board approval and do not require informed consent from participants.

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Data availability statement Data are available upon reasonable request. The data set from this study is held securely in coded form at the Institute for Clinical Evaluative Sciences (ICES). While data sharing agreements prohibit ICES from making the data set publicly available, access may be granted to those who meet prespecified criteria for confidential access, available at www.ices.on.ca/DAS.

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