Association Between Physicians' Appropriate Use of Echocardiography and Subsequent Healthcare Use and Outcomes in Patients With Heart Failure

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Background—There is little understanding of whether a physician's tendency to order an inappropriate cardiac service is associated with the use of other cardiac services and clinical outcomes in their patients with heart failure (HF).

Methods and Results—We conducted a secondary analysis of 35 Ontario-based cardiologists who participated in the control arm of the Echo WISELY (Will Inappropriate Scenarios for Echocardiography Lessen Significantly) trial. Transthoracic echocardiograms, ordered during the trial, were classified as rarely appropriate (rA), appropriate, or maybe appropriate on the basis of the 2011 appropriate use criteria. Cardiologists were grouped into tertiles of rA transthoracic echocardiogram ordering frequency: low ordering (bottom tertile), n=11; moderate ordering, n=12; or high ordering (top tertile), n=12. The main outcomes were measures of cardiac service use, including cardiology-related physician visits, tests, and medications. Among 1677 patients with heart failure and an outpatient visit to 1 of 35 cardiologists, we found no significant association between rA transthoracic echocardiogram ordering frequency (by tertile) and cardiac testing use, although patients of cardiologists in the high ordering group had fewer physician visits, on average, than patients seen by low ordering cardiologists. In addition, patients of cardiologists in the highest rA ordering tertile had significantly lower odds of receiving potentially effective interventions, such as β blockers (odds ratio, 0.62; 95% CI, 0.43–0.89), than the low ordering group.

Conclusions—Although patients of cardiologists who frequently order rA transthoracic echocardiograms do not appear more (or less) likely to have subsequent cardiac tests, these patients have fewer follow-up visits and lower odds of receiving evidence-based medications.

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Key Words: appropriateness criteria • healthcare use • low-value care • overuse

The Institute of Medicine classifies problems on health-care quality into 3 categories: overuse, underuse, and misuse.[1] Historically, quality improvement efforts have largely focused on underuse and misuse. Overuse describes the provision of healthcare services in clinical scenarios where medical justification is absent or insufficient or where the

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ORIGINAL RESEARCH

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Clinical Perspective

What Is New?

- It is unknown whether a physician's tendency to order low-value care, such as rarely appropriate transthoracic echocardiography, is associated with increases in overall healthcare use and differences in patient outcomes.
- Among a cohort of patients with heart failure (HF), we found that high ordering physicians of rarely appropriate care had lower rates of outpatient cardiologist visits and lower rates of β blocker and implanted cardioverter use, but similar rates of other cardiac tests.
- More important, we reported no differences in 1-year outcomes among patients with HF between groups, which demonstrates a lack of correlation between appropriateness, testing use, and outcomes in this cohort.

What Are the Clinical Implications?

- Our study is the first to link ordering appropriateness with other areas of physician behavior, such as overall cardiac testing, intervention, and medication use, and more important, clinical outcomes, such as mortality and hospitalization.
- This study provides important insight into the relationship between appropriateness of cardiac services and outcomes in HF, which may be used to help design optimal treatment strategies for patients with HF.
- These findings may also be used in the design of interventions assessing appropriate use criteria as a quality improvement tool in the context of HF.

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potential benefits are exceeded by the potential harms,[1,2] leading to low-value care. Consequently, overuse can result in additional, downstream care for patients, while increasing system-level wait times and healthcare costs associated with the overused services.[3,4] The importance of overuse is being increasingly recognized in more recently developed quality improvement initiatives, such as the appropriate use criteria (AUC) developed by the American College of Cardiology and related societies.[5]

To discourage overuse, the AUC identify cardiac services (primarily tests and procedures) that are low value. Prior studies of clinical practice have estimated that the frequency of low-value cardiac testing ranges between 10% and 30% among cardiologists.[6] Most of the prior studies have examined rates of low-value care in isolation, which provides a limited picture into a clinician's practice with overall quality of care. For example, it is not known whether a cardiologist's tendency to order rarely appropriate (rA) transthoracic echocardiograms (TTEs), an example of low-value care, is associated with the tendency to order other low-value tests, or conversely, order high-value care, such as evidence-based

medications in patients with heart failure (HF). More important, the relationship between a physician's tendency to order rA TTEs and patient outcomes is unknown.

In the current study, we primarily aim to study the association between physicians' tendency to order low-value care, specifically rA TTEs, and the use of other cardiac services in patients with HF. As a secondary aim, we will study the association between a physician's tendency to order rA TTEs and outcomes in patients with HF. We hypothesize that cardiologists who order rA TTEs with higher frequency will also have greater overall healthcare use compared with cardiologists who order rA TTEs less frequently, with no differences in patient outcomes.

Methods

Study Design and Setting

We conducted a population-based, retrospective cohort study of cardiologists' and HF outpatients under their care using administrative claims data in Ontario, Canada, and clinical data collected for the Echo WISELY (Will Inappropriate Scenarios for Echocardiography Lessen Significantly) trial (ClinicalTrials.gov NCT02038101) between December 1, 2014, and October 31, 2016. All data were linked and analyzed at the Institute for Clinical and Evaluative Sciences. The use of data for this study was authorized under §45 of Ontario's Personal Health Information Protection Act, which does not require review by a research ethics board.

Data Sources

We conducted a secondary analysis of physicians who participated in the control arm of the Echo WISELY trial, which tested the effect of an educational intervention (including audit and feedback) on reducing rA TTEs, using the 2011 AUC[5] for echocardiography. Physicians in the control group received no education or feedback on their TTE ordering patterns and were only informed their ordering appropriateness would be recorded during the study period. The study protocol and main study results have been published previously.[7,8] The Echo WISELY trial database provides the clinical indication, AUC classification, and ordering physician identifier for TTEs ordered during the study. The ordering physician identifier was used to link trial participants with administrative claims data held at the Institute for Clinical and Evaluative Sciences. Physician characteristics were obtained from the Institute for Clinical and Evaluative Sciences Physician Database, including years since graduation, sex, international medical graduate status, and workload.[9] The Ontario Health Insurance Plan database contains billing claims for healthcare services covered by the

provincial government and rendered to patients with an Ontario health card number.[10] The Registered Persons Database contains sociodemographic information on patients with an Ontario health card, including age, sex, rurality, and postal code. The Postal Code Conversion File was used to determine patients' quintile of neighborhood income.[11] History of hypertension, diabetes mellitus, and chronic obstructive pulmonary disease was obtained from corresponding disease-specific registries. The CorHealth registry, previously known as the Cardiac Care Network, contains information on patient history of cardiovascular disease and cardiac-related tests, treatments, and procedures, including cardiac catheterization and coronary artery bypass grafting.[12]

Cohort Selection

The Echo WISELY trial was conducted at 8 academic hospitals (7 in Ontario, Canada, and 1 in the United States) and included both primary care practitioners and cardiologists. In this study, we first identified all Ontario-based cardiologists who enrolled in the Echo WISELY trial and who were allocated to the control group and restricted the cohort to patients seen by these physicians. The focus on Ontario cardiologists enables linkage with provincial administrative and billing data, whereas the exclusion of treatment arm participants was informed by the positive intervention effect observed in the main study.[8] We also excluded any cardiologists who ordered <1 TTE/month or <25 TTEs over the 18-month study period (September 2014 to May 2016) to ensure TTE ordering habits would be based on a suitable sample of tests.[8] Last, we excluded any physicians with a missing identifier because of death during follow-up, which would preclude linkage with administrative data.

After identifying the cardiologists in the study, we then identified all in-office, outpatient visits made to each cardiologist between December 1, 2014, and October 1, 2016 (n=68 631). Table S1 describes all the Ontario Health Insurance Plan fee codes used to identify outpatient cardiology visits. We excluded any visits involving patients who were non-Ontario residents, were in a long-term care facility, or had invalid or missing sociodemographic information (health card number, age, sex, or income quintile). We then identified outpatient visit claims involving patients with a history of HF in the 3 years before their outpatient visit, defined as at least one hospitalization or emergency department visit with an *International Classification of Diseases, Tenth Revision* (*ICD-10*), code I50 listed as the most responsible diagnosis and not as a postadmission comorbidity.[13–15] For patients with multiple eligible outpatient visits, we excluded any visits that occurred on the same day as another outpatient cardiology visit billed by a different cardiologist. This was done to reduce the risk of misclassifying the physician responsible for a given patient's cardiac care. Among the resulting pool of visits per patient, we only selected each patient's first eligible visit by date. Within our cohort, if patients had multiple hospitalizations or emergency department visits with HF as the most responsible diagnosis within the 3-year look-back window from their index visit, we selected the most recent claim to rule the patient in and noted the date.

Exposure

Using the Echo WISELY trial database, we calculated the proportion of all TTEs ordered by a given cardiologist during the Echo WISELY trial that were classified as rA according to the 2011 AUC. We then classified cardiologists into tertiles on the basis of their rA TTE use, a characteristic intended to serve as a proxy of their overall tendency to order low-value care. Cardiologists were placed into 1 of 3 categories: low (bottom tertile), moderate, or high (top tertile) orderers of rA TTEs.

Outcomes

The main outcomes were downstream diagnostic tests and procedures, for which we independently identified whether patients had any of the following tests (at least once) within 1 year of their index visit: TTE; left ventricle ejection fraction assessment; stress test; cholesterol assessment; or hemoglobin A1c measurement. In addition, we identified whether patients had any of the following procedures performed within 1 year: cardiac catheterization; coronary revascularization (coronary artery bypass graft or percutaneous coronary intervention); or implantation of a cardioverter defibrillator. These indicators were selected because they are common cardiac tests and procedures mentioned in the American College of Cardiology/American Heart Association guidelines for the management of HF.[16,17]

Secondary outcomes included additional measures of healthcare use and adverse clinical outcomes at 1 year. First, we independently observed the frequency of follow-up physician visits (ie, visit with family physician, cardiologist, or cardiac surgeon). In addition to this composite visit frequency outcome, we separately counted the number of outpatient visits to a family physician, as well as the frequency of outpatient cardiologist or cardiac surgeon visits (outpatient and nonemergency inpatient). We also captured the frequency of emergency department visits. For hospitalizations, we independently identified whether patients had at least one hospitalization for any reason, an acute myocardial infarction, HF, or stroke. In addition, we captured whether patients had at least one cardiovascular disease–related emergency department visit or hospitalization. Last, we identified whether patients died (all-cause mortality; modeled as a dichotomous outcome).

Among patients aged ≥65 years as of their index visit, we observed whether they filled at least one prescription for each of the following medications: angiotensin system inhibitor, antiplatelet, β blocker, aldosterone receptor antagonist, statin, diuretic, nitrate, or digoxin. The age restriction was done to ensure patients' prescription claims would be captured in the Ontario Drug Benefit database, as older Ontario residents, aged ≥65 years, have prescription drug coverage under the Ontario Drug Benefit.

Table S1 contains full definitions for all outcomes observed.

Covariates

We measured several sociodemographic and clinical patient characteristics, including age, sex, rurality, neighborhood income quintile, history of cardiovascular disease (including myocardial infarction, stroke, peripheral vascular disease, hyperlipidemia, and hypertension), prior coronary revascularization procedure, and chronic conditions (ie, chronic obstructive pulmonary disease, diabetes mellitus, and renal dysfunction). In addition, we measured the amount of time elapsed (in days) between the patient's most recent HF-related claim before his/her index visit and his/her index visit date (treated as continuous). In addition to the primary exposure, we also captured cardiologist sex, years since medical school graduation (treated as continuous), and international medical graduate status.

Statistical Analysis

All patient and provider characteristics were summarized at baseline by rA ordering tertile via frequencies and percentages for categorical variables and medians and interquartile ranges for continuous variables. Significant differences in baseline characteristics were assessed among ordering tertiles via χ^2 tests of independence (or Fisher exact tests, where appropriate) for categorical variables and Kruskal-Wallis tests for continuous variables.

To assess the association between rA ordering tertile (low as reference category) and our dichotomous outcomes, we used multivariable mixed-effects logistic regression. All models adjusted for all patient and physician characteristics listed in the Covariates section. Random intercepts were included to account for correlation among patients under the care of the same cardiologist.

Multivariable mixed-effects Poisson regression was used to assess the association between rA ordering tertile (low as reference category) and count-based (ie, frequency) outcomes. Detection of significant overdispersion via Lagrange multiplier tests resulted in alternative specification of a negative binomial versus Poisson distribution. Models were adjusted for the same fixed and random effects as our logistic regression models detailed in the previous paragraph.

All analyses were performed in SAS 9.4 (SAS Institute) with statistical significance assessed via a 2-tailed $P \leq 0.05$.

Results

Physician Participants

In the original Echo WISELY trial, 179 physicians were included in the final analysis; however, only 153 physicians (134 cardiologists and 19 primary care physicians) ordered at least 1 classifiable TTE during the study period, of which 79 physicians were allocated to the control group. After limiting to Canadian cardiologists in the control group, excluding those who ordered <25 TTEs over the study period (n=3), and excluding one cardiologist because of missing data, a total of 35 cardiologists in the control group were included in the current study. These 35 cardiologists ordered a total of 4968 TTEs, of which 684 were deemed rA. The 35 cardiologists had a mean of 25.0±11.2 years in practice, 77% were men, and 91% were Canadian trained. Among our cohort of 35 cardiologists, the mean number of rA TTEs ordered was 3.3 in the low ordering group (n=11), 15.5 in the moderate ordering group (n=12), and 38.5 in the high ordering group (n=12). The median physician-level rA TTE ordering rate was 11% (quartile 1–quartile 3, 8%–16%). The mean frequency of rA TTE ordering ranged from 0.0% to 9.0% in the low ordering group, from 9.3% to 13.6% in the moderate ordering group, and from 14.1% to 35.0% in the high ordering group.

Patient Participants

As shown in the cohort creation diagram (Figure), a total of 68 631 outpatient cardiology visits were assessed for eligibility. After exclusion of visits that did not meet eligibility criteria, a total of 1677 patients with HF (mean age, 72.1±13.6 years; 61.5% men) were included in the analysis. Demographic and clinical data for patients are presented in Table 1. Patients belonging to cardiologists in the frequent rA TTE tertile were, on average, older; and although there were some differences in the rates of prior myocardial infarction, hypertension, and hyperlipidemia, most of the patients' characteristics were similar across the 3 groups.

Downstream Diagnostic and Therapeutic Procedures After Index Visit

After adjusting for physician- and patient-level characteristics, we found no significant association between cardiologists' rA TTE ordering frequency (by tertile) and their patients' odds of having any of the cardiac tests we investigated (Table 2).
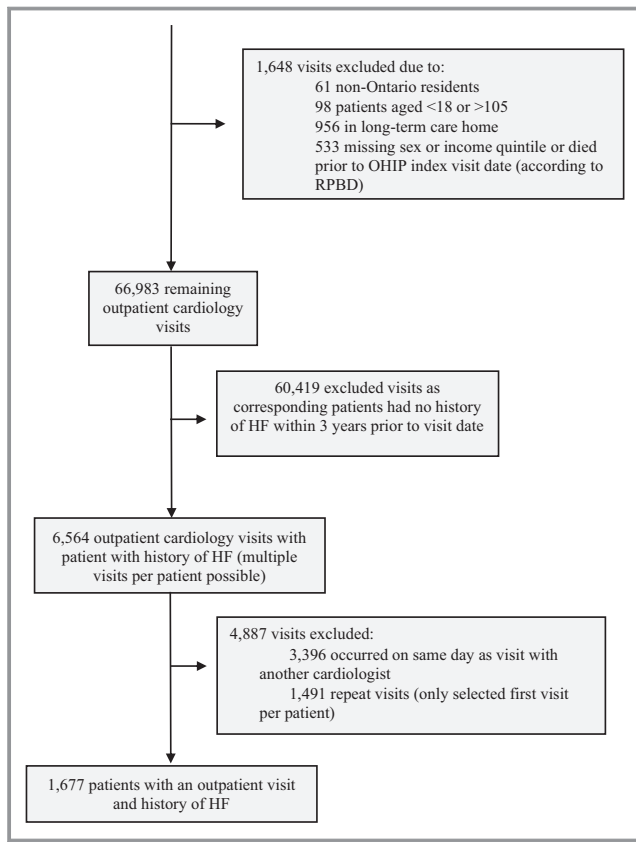
Figure. Cohort creation diagram. HF indicates heart failure; OHIP, Ontario Health Insurance Plan; RPDB, Registered Persons Database.

Table 2 also presents the results of mixed-effects logistic regression analyses on the use of cardiac procedures over 1 year of follow-up among patients with HF. Patients seen by a cardiologist in the high or moderate frequency of rA TTE ordering groups had significantly lower odds of having a cardioverter defibrillator implanted at 1 year compared with patients of a cardiologist in the low ordering group; however, no statistically significant differences in patients' odds of a cardiac catheterization or coronary revascularization procedure were observed on the basis of cardiologists' tertile of rA ordering frequency.

Medication Use and Implantation of Cardioverter Defibrillators

Table 3 presents the results of mixed-effects logistic regression analysis for medication use among patients with HF aged ≥65 years. After adjusting for several patient- and physician-level characteristics, medication use was generally similar across the tertiles, although patients in the high ordering group were less likely to be prescribed β blockers (odds ratio, 0.62; 95% CI, 0.43–0.89). Patients in the moderate ordering group were less likely to be prescribed antiplatelet agents

(odds ratio, 0.62; 95% CI, 0.44–0.86) and more likely to be prescribed nitrates (odds ratio, 1.64; 95% CI, 1.06–2.54) and digoxin (odds ratio, 2.47; 95% CI, 1.59–3.85).

Physician Visits

Table 4 presents our multivariable mixed-effects Poisson regression results for outcomes measuring frequency of visits among patients with HF. We reported no significant association between rA TTE ordering tertile and overall frequency of physician visits within 1 year. However, patients of cardiologists in the high ordering group had fewer outpatient cardiologist visits, on average, compared with patients seen by cardiologists in the low ordering group [RR (relative risk), 0.61; 95% CI, 0.43–0.86].

Adverse Clinical Outcomes

Table 5 demonstrates the adjusted clinical outcomes at 1 year. After adjusting for patient and cardiologist characteristics, cardiologists' rA TTE ordering frequency was not associated with the occurrence (or frequency) of adverse clinical outcomes at 1 year.

Discussion

In this study assessing the practice patterns of cardiologists who were part of the control arm of a large randomized control trial assessing appropriateness of test ordering, we observed high ordering physicians of rA TTEs had lower rates of outpatient cardiologist visits and lower rates of β-blocker and implanted cardioverter defibrillator use, but similar rates of other cardiac testing. More important, there were no differences in 1-year outcomes between patients with HF between groups. The results demonstrate a lack of correlation between appropriateness, testing use, and outcomes in this cohort. More important, physicians in the low ordering group did not underuse other cardiac services compared with high ordering physicians. To the best of our knowledge, the current study is the first to link physician-level ordering appropriateness with other aspects of physician behavior, such as overall cardiac testing, intervention, and medication use, and more important, outcomes; and it has important implications for the use of AUC as a quality improvement tool and interventions designed to improve appropriateness of testing.

Prior research has demonstrated that more frequent ordering of low-value services is generally associated with frequent ordering of high-value (or necessary) services. A study by Ko and colleagues comparing coronary revascularization rates in New York State versus Ontario, Canada, found higher rates of discretionary revascularization, along with

Table 1. Characteristics of Patients With HF at Time of Index Outpatient Cardiology Visit, Stratified by Cardiologists' rA TTE Ordering Frequency (n=1677 Patients)

Characteristic	Total	Cardiologists' rA TTE Ordering Frequency			P Value
		Low (Tertile 1)	Moderate (Tertile 2)	High (Tertile 3)	
No. of patients	1677	514	609	554	...
Age, median (quartile 1–quartile 3), y	75 (64–82)	75 (66–82)	70 (59–81)	77 (66–84)	<0.0001
Sex, n (%)					0.001
Men	1031 (61.5)	348 (67.7)	368 (60.4)	315 (56.9)	
Women	646 (38.5)	166 (32.3)	241 (39.6)	239 (43.1)	
Live in rural area, n (%)	134 (8.0)	37 (7.2)	57 (9.4)	40 (7.2)	0.30
Neighborhood income quintile, n (%)					
1 (Lowest)	350 (20.9)	113 (22.0)	122 (20.0)	115 (20.8)	0.69
2	362 (21.6)	121 (23.5)	129 (21.2)	112 (20.2)	
3	294 (17.5)	86 (16.7)	115 (18.9)	93 (16.8)	
4	306 (18.2)	85 (16.5)	118 (19.4)	103 (18.6)	
5 (Highest)	365 (21.8)	109 (21.2)	125 (20.5)	131 (23.6)	
Prior myocardial infarction, n (%)	284 (16.9)	104 (20.2)	84 (13.8)	96 (17.3)	0.016
Prior coronary revascularization, n (%)	259 (15.4)	90 (17.5)	80 (13.1)	89 (16.1)	0.12
Renal dysfunction, n (%)	606 (36.1)	167 (32.5)	247 (40.6)	192 (34.7)	0.013
Previous stroke, n (%)	150 (8.9)	46 (8.9)	56 (9.2)	48 (8.7)	0.95
PVD, n (%)	196 (11.7)	54 (10.5)	79 (13.0)	63 (11.4)	0.42
COPD, n (%)	642 (38.3)	194 (37.7)	229 (37.6)	219 (39.5)	0.76
Hyperlipidemia, n (%)	1296 (77.3)	412 (80.2)	441 (72.4)	443 (80.0)	0.002
Diabetes mellitus, n (%)	916 (54.6)	271 (52.7)	326 (53.5)	319 (57.6)	0.22
Hypertension, n (%)	1511 (90.1)	466 (90.7)	531 (87.2)	514 (92.8)	0.005
Lag time between HF and index visit date, median (quartile 1–quartile 3), d	117 (30–407)	202 (42–474)	101 (28–361)	88 (28–378)	<0.001

P values for continuous variables (median [quartile 1–quartile 3]) reported from Kruskal-Wallis test, whereas P values for categorical variables (number [percentage]) reported from χ^2 tests of independence. COPD indicates chronic obstructive pulmonary disease; HF, heart failure; PVD, peripheral vascular disease; rA, rarely appropriate; TTE, transthoracic echocardiogram.

higher rates of emergency revascularization for acute myocardial infarction.[18] There does exist significant unexplained treatment variation across regions and countries that may relate to local treatment practices. For example, a study of treatment practices for acute myocardial infarction across Canada and the United States found higher rates of coronary revascularization in the western United States, with higher medication use in Ontario and northeastern United States, which suggests local practice significantly influences patient treatment plans, beyond a simple overuse/underuse paradigm.[19] Further work has also demonstrated that regional differences exist in the treatment of patients with HF that may relate to both local clinical practice and health system differences.[20] Our study expands on these prior findings, by demonstrating that at an individual physician level, overuse of cardiac testing does not necessarily correlate with underuse of needed cardiac therapy. One difference in our results

compared with prior research is that the median rA rate of 11% for TTE is lower than in previously published studies, which report an rA ordering rate for TTE of 13% to 30%.[21,22] The lower rA ordering rate is likely because the cardiologists in this study are predominantly academic cardiologists and possibly because of the Hawthorne effect, where participants modify their behavior in response to being observed.[8,23]

AUC were developed to guide optimal use of a variety of medical tests and procedures for the delivery of high-quality care, mainly in response to the growing use of cardiac testing.[5,24] Prior research has tested various strategies to improve cardiac testing appropriateness, including education, audit, and feedback, along with decision support.[8,21,25–28] One major concern raised about such interventions is the potential unintended consequence of increasing underuse of needed services, leading to worse clinical outcomes.[29,30] Although this specific study was not designed to determine

Table 2. Association Between Cardiologists' Frequency of rA TTE Ordering With Downstream Use of Cardiac Services Over 1 Year Among 1623 Patients With HF

Outcome	rA TTE Ordering Frequency	Adjusted OR (95% CI)*
Tests at 1 y		
TTE	High	1.18 (0.74–1.87)
	Moderate	1.14 (0.72–1.82)
	Low	Reference
LVEF assessment	High	1.16 (0.73–1.86)
	Moderate	1.14 (0.71–1.83)
	Low	Reference
Stress test, exercise test, or nuclear stress test	High	1.13 (0.73–1.77)
	Moderate	0.95 (0.61–1.48)
	Low	Reference
Cholesterol assessment	High	0.78 (0.58–1.04)
	Moderate	0.82 (0.62–1.09)
	Low	Reference
Hemoglobin A1c measurement	High	0.72 (0.51–1.02)
	Moderate	0.76 (0.53–1.07)
	Low	Reference
Procedures at 1 y		
Cardiac catheterization	High	0.91 (0.35–1.82)
	Moderate	0.69 (0.26–1.82)
	Low	Reference
Coronary revascularization	High	1.23 (0.39–3.84)
	Moderate	0.46 (0.14–1.53)
	Low	Reference
Implantation of cardioverter defibrillator	High	0.35 (0.15–0.82)[†]
	Moderate	0.40 (0.18–0.91)[†]
	Low	Reference

HF indicates heart failure; LVEF, left ventricle ejection fraction; OR, odds ratio; rA, rarely appropriate; TTE, transthoracic echocardiogram.
*Adjusted OR estimated using multivariable mixed-effects logistic binomial regression with adjustment for the following covariates: patient characteristics (age, sex, rurality, neighborhood income quintile, indicators of prior cardiovascular disease and other chronic comorbidities [ie, acute myocardial infarction, stroke, hypertension, hyperlipidemia, diabetes mellitus, renal dysfunction, chronic obstructive pulmonary disease, and peripheral vascular disease], and prior coronary revascularization) and physician characteristics (sex, years since graduation, and international medical graduate status).
[†]Statistically significant at *P*≤0.05.

Table 3. Association Between Cardiologists' Frequency of rA TTE Ordering With Prescription Medication Use Among 1186 Patients With HF Aged ≥65 Years

Outcome	rA TTE Ordering Frequency	Adjusted OR (95% CI)*
Angiotensin system inhibitor[†]	High	0.84 (0.55–1.30)
	Moderate	0.93 (0.60–1.44)
	Low	Reference
Antiplatelet	High	0.86 (0.62–1.21)
	Moderate	0.62 (0.44–0.86)[‡]
	Low	Reference
β Blocker	High	0.62 (0.43–0.89)[‡]
	Moderate	0.75 (0.52–1.10)
	Low	Reference
Aldosterone receptor antagonist	High	0.70 (0.38–1.30)
	Moderate	0.88 (0.47–1.63)
	Low	Reference
Statin	High	0.93 (0.64–1.34)
	Moderate	0.71 (0.50–1.03)
	Low	Reference
Diuretic	High	0.94 (0.52–1.70)
	Moderate	1.05 (0.57–1.93)
	Low	Reference
Nitrate	High	1.51 (0.99–2.33)
	Moderate	1.64 (1.06–2.54)[‡]
	Low	Reference
Digoxin	High	1.16 (0.72–1.87)
	Moderate	2.47 (1.59–3.85)[‡]
	Low	Reference

Regression sample only included patients aged ≥65 years because of Ontario Drug Benefit data availability. HF indicates heart failure; OR, odds ratio; rA, rarely appropriate; TTE, transthoracic echocardiogram.
*Adjusted OR estimated using multivariable mixed-effects logistic regression with adjustment for the following covariates: patient characteristics (age, sex, rurality, neighborhood income quintile, indicators of prior cardiovascular disease and other chronic comorbidities [ie, acute myocardial infarction, stroke, hypertension, hyperlipidemia, diabetes mellitus, renal dysfunction, chronic obstructive pulmonary disease, and peripheral vascular disease], and prior coronary revascularization) and physician characteristics (sex, years since graduation, and international medical graduate status).
[†]Includes angiotensin-converting enzyme inhibitor or angiotensin receptor blocker.
[‡]Statistically significant at *P*≤0.05.

the impact of an appropriateness intervention on clinical outcomes, the lack of differences in both use of evidence-based therapy and clinical outcomes between low and high orderers indirectly suggests that improving appropriateness does not lead to underuse of needed cardiac services or worse clinical outcomes. Numerous initiatives to improve the adherence to guideline-based therapy that incorporate recommendations on both overuse and underuse, coupled with overuse awareness campaigns, like Choosing Wisely, have equated the idea of appropriateness with quality care.[24,31] Thus, it is possible that physicians who infrequently order inappropriate services may simply be adhering more closely to guideline-based care, which would explain the higher rates of some guideline-based therapy, such as β-blocker use or cardioverter defibrillator implantation.

Table 4. Association Between Cardiologists' Frequency of rA TTE Ordering With Frequency of Physician Visits Over 1 Year Among 1623 Patients With HF

Outcome*	rA TTE Ordering Frequency	Adjusted RR (95% CI)[†]
No. of physician visits[‡]	High	0.83 (0.64–1.07)
	Moderate	0.82 (0.63–1.06)
	Low	Reference
No. of outpatient cardiologist visits	High	0.61 (0.43–0.86)[§]
	Moderate	0.76 (0.54–1.07)
	Low	Reference
No. of outpatient primary care visits	High	1.07 (0.87–1.31)
	Moderate	1.10 (0.90–1.36)
	Low	Reference
No. of cardiologist/ cardiac surgeon visits	High	1.36 (0.64–2.89)
	Moderate	1.43 (0.67–3.06)
	Low	Reference

HF indicates heart failure; rA, rarely appropriate; TTE, transthoracic echocardiogram; RR, relative risk.

*For patients with multiple eligible outpatient visits, we excluded any visits that occurred on the same day as another outpatient cardiology visit billed by a different cardiologist. This was done to reduce the risk of misclassifying the physician responsible for a given patient's cardiac care.

[†]Adjusted RR (relative risk) estimated using multivariable mixed-effects Poisson regression with adjustment for the following covariates: patient characteristics (age, sex, rurality, neighborhood income quintile, indicators of prior cardiovascular disease and other chronic comorbidities [ie, acute myocardial infarction, stroke, hypertension, hyperlipidemia, diabetes mellitus, renal dysfunction, chronic obstructive pulmonary disease, and peripheral vascular disease], and prior coronary revascularization) and physician characteristics (sex, years since graduation, and international medical graduate status).

[‡]Includes visits involving general practitioners (primary care), cardiologists, or cardiac surgeon.

[§]Statistically significant at *P*≤0.05.

Table 5. Association Between Cardiologists' Frequency of rA TTE Ordering With Occurrence of Adverse Clinical Outcomes Over 1 Year Among 1623 Patients With HF

Outcome*	rA TTE Ordering Frequency	Adjusted OR (95% CI)[†]
Adverse clinical outcomes at 1 y		
Death (all cause)	High	1.10 (0.73–1.65)
	Moderate	0.78 (0.52–1.17)
	Low	Reference
Hospitalization (all cause)	High	1.06 (0.74–1.53)
	Moderate	1.00 (0.69–1.43)
	Low	Reference
Acute MI hospitalization	High	0.95 (0.42–2.14)
	Moderate	1.05 (0.47–2.36)
	Low	Reference
HF hospitalization	High	1.06 (0.72–1.57)
	Moderate	1.08 (0.73–1.61)
	Low	Reference
Stroke hospitalization	High	1.13 (0.32–3.97)
	Moderate	2.85 (0.87–9.38)
	Low	Reference
Hospitalization or ED visit for CVD	High	1.26 (0.92–1.73)
	Moderate	1.24 (0.91–1.69)
	Low	Reference
Adjusted RR (95% CI)[†]		
Frequency of ED visits	High	0.85 (0.67–1.07)
	Moderate	0.87 (0.68–1.10)
	Low	Reference

Statistically significant at *P*≤0.05. CVD indicates cardiovascular disease; ED, emergency department; HF, heart failure; MI, myocardial infarction; OR, odds ratio; rA, rarely appropriate; TTE, transthoracic echocardiogram.

*We only selected each patient's first eligible visit by date. If patients had multiple hospitalizations or ED visits with HF as the most responsible diagnosis within the 3-year look-back window from their index visit, we selected the most recent claim to rule the patient in and noted the date.

[†]Adjusted OR estimated using multivariable mixed-effects logistic regression, whereas adjusted RR estimated using multivariable mixed-effects Poisson regression. All estimates were adjusted for the following covariates: patient characteristics (age, sex, rurality, neighborhood income quintile, indicators of prior cardiovascular disease and other chronic comorbidities [ie, acute myocardial infarction, stroke, hypertension, hyperlipidemia, diabetes mellitus, renal dysfunction, chronic obstructive pulmonary disease, and peripheral vascular disease], and prior coronary revascularization) and physician characteristics (sex, years since graduation, and international medical graduate status).

This study's findings should be considered within the context of its important limitations. First, all cardiologists included in this study were academic cardiologists (which may explain the minimal variability in rA TTE ordering frequency among participating cardiologists), limiting the generalizability of the study to the community setting. Second, although appropriateness of TTE was known, the appropriateness of other cardiac testing and treatments was not, such as medication use and other testing information. In addition, we lacked echocardiographic data for these patients; thus, we could not tell whether the patients had preserved or reduced left ventricular systolic function. We do not know the subspecialty of the cardiologists included in the study and could not determine which ones, if any, were HF specialists versus general cardiologists. Finally, in our analyses, we did not assess whether observed associations were modified by patient or physician sociodemographic characteristics, through the inclusion of statistical interaction terms. Despite these limitations, this study provides important insights into the physician-level relationship between TTE appropriateness, cardiac test and treatment use, and outcomes in patients with HF.

Conclusions

In this study of cardiologists' appropriateness rates, high ordering cardiologists did not have higher rates of cardiac

testing use or treatments than low ordering cardiologists, but did demonstrate lower use of potentially effective services, such as prescription medications for HF management, and fewer physician visits. This study highlights the need for research studying the relationship between appropriateness of cardiac services and outcomes in patients with HF to best design optimal HF treatment strategies.

Disclosures

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SUPPLEMENTAL MATERIAL

Table S1. Inclusion and exclusion criteria definitions.

Criteria	Definition
Outpatient cardiology visit definition	Any OHIP claim with LOCATION=O (office) and at least one of the following OHIP fee codes: ● A605 = Consultation (patient 17+) ● A600 = Comprehensive cardiology consultation ● A675 = Limited consultation ● A606 = Repeat consultation ● A603 = Medical specific assessment ● A604 = Medical specific re-assessment ● A601 = Complex medical specific re-assessment ● A608 = Partial assessment

History of heart failure	Patient must satisfy at least one of the following definitions:
	● **Acute myocardial infarction:**
	  ● DAD or NACRS claim with ICD-10 code I21 or I22 as the most responsible diagnosis
	● **Coronary revascularization (PCI or CABG)**
	  ● CCI codes for CABG: 1IJ76
	  ● CCI codes for PCI: 1IJ50, 1IJ57GQ, 1IJ54
	  ● CCN definition for PCI: Primary reason for referral is coronary artery disease (RemovalReasonCD='PS' AND removaldate > 0 AND (Cath_ScheduledPciIND=Y OR Cath_StagedPciIND=Y OR Cath_SSPiIND=Y)
	    ● *Note: IF Cath_InterventionProcAbortedIND='Y' or Cath_DiagnosticProcAbortedIND='Y' then remove
	  ● CCN definition for isolated CABG: RemovalReasonCD='PS' AND surgery_bypassSurgeryIND=Y and surgery_aorticValvesurgeryIND=N and surgery_mitralvalveSurgeryIND=N and TricuspidvalveSurgeryIND=N and Surgery_otherValveSurgeryIND=N
	● **Cardiac catheterization with evidence of significant epicardial coronary stenosis**
	● Coronary angiogram (Y) with angiographic findings of either: left main artery stenosis of >=50%

	or stenosis of >=70% of main epicardial coronary artery (LAD [proximal or mid/distal], circumflex artery or RCA) defined below:
	
	o *Left main artery stenosis*: Coronary angiogram Native stenosis LM (CATH_NATIVELMCD=Y='Yes>=50%')
	
	o *Stenosis of >=70% of main epicardial coronary artery* – any of the following qualify:
	
	    ▪ Coronary angiogram Native Stenosis-Prox LAD (CATH_NATIVEPROXLADCD=Y='Yes>=70%')
	
	    ▪ Coronary angiogram Native Stenosis-Mid/distal LAD (CATH_NATIVEMIDDISTALLADCD='Yes >=70%')
	
	    ▪ Coronary angiogram Native Stenosis-Circumflex (CATH_NATIVECIRCUMFLEXCD=Y='Yes >=70%')
	
	    ▪ Coronary angiogram Native Stenosis-RCA (CATH_NATIVERCACD=Y='Yes>=70%')
	
	*Note: IF Cath_InterventionProcAbortedIND='Y' OR Cath_DiagnosticProcAbortedIND='Y' then remove as procedure was aborted.

OHIP= Ontario Health Insurance Plan; DAD= Discharge Abstract Database; NACRS= National Ambulatory Care Reporting System; CCI= Classification of Health Interventions; PCI=percutaneous coronary intervention; CABG= coronary artery bypass and graft; CCN= Canadian Cardiovascular Network; LAD= left anterior descending artery; RCA= right coronary artery.