



## Clinical Research

# Automated Referral to Cardiac Rehabilitation After Coronary Artery Bypass Grafting Is Associated With Modest Improvement in Program Completion

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## ABSTRACT

**Background:** Cardiac rehabilitation (CR) is a guideline-indicated modality for reducing residual cardiovascular risk among patients undergoing coronary artery bypass grafting (CABG) surgery. However, many referred patients do not initiate or complete a CR program; even more patients are never even referred.

**Methods:** All post-CABG patients in Calgary, Alberta, Canada, from January 1, 1996, to March 31, 2016, were included. Data were obtained from the Alberta Provincial Project for Outcome Assessment in Coronary Heart Disease and TotalCardiology Rehabilitation databases. Automated referral to CR at discharge after CABG was instituted on July 1, 2007. We used interrupted time series analysis to evaluate the

## RÉSUMÉ

**Contexte :** La réadaptation cardiaque (RC) est une modalité recommandée dans les lignes directrices afin de diminuer le risque cardiovasculaire résiduel chez les patients qui ont subi un pontage aortocoronarien (PAC). Toutefois, bon nombre de patients orientés en RC ne commencent ou ne terminent pas le programme qui leur est proposé, et encore plus de patients ne sont jamais orientés en RC.

**Méthodologie :** Tous les patients ayant subi un PAC à Calgary, en Alberta (Canada) entre le 1<sup>er</sup> janvier 1996 et le 31 mars 2016 ont été inclus dans l'étude. Les données sont tirées des bases de données de l'Alberta Provincial Project for Outcome Assessment in Coronary Heart Disease et de la clinique TotalCardiology Rehabilitation. Depuis le 1<sup>er</sup>

Coronary artery bypass grafting (CABG) surgery is a well established therapy that improves survival and quality of life for patients with coronary artery disease (CAD).<sup>1</sup> However, the risk factors that led to CAD remain present after CABG surgery and patients remain at risk for further ischemic events owing to graft atherosclerosis or progression of native CAD.<sup>2</sup>

Cardiac rehabilitation (CR) is a guideline-indicated modality for reducing residual cardiovascular risk in post-CABG patients.<sup>3</sup> Completing a CR program after CABG improves cardiopulmonary fitness and medication adherence and decreases subsequent CAD morbidity and mortality.<sup>4,5</sup> However, many referred patients do not initiate or complete a CR program; even more patients are not given the opportunity to attend because they are never referred to a CR program.<sup>6</sup>

CR referral rates are variable, with some reports suggesting that more than 80% of eligible patients are never referred.<sup>7</sup> Lack of standardization of clinical practice is an important barrier.<sup>8</sup> Systematic referral strategies have been demonstrated to be effective in increasing referral rates, including an automated referral system using electronic medical records or

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impact of automated referral on CR referral and completion rates and studied the association of these CR process markers with mortality.

**Results:** A total of 8,118 patients underwent CABG surgery during the study period: 5,103 before automation and 3,015 after automation. Automation increased referral rates from 39.5% to 75.0% ( $P < 0.001$ ). Automated referral was associated with a 7.2% increase in CR completion in the overall population (33.3% vs 26.1%;  $P < 0.001$ ). In adjusted models, CR referral alone was not associated with reduced mortality (hazard ratio [HR] 0.84, 95% CI 0.64-1.11), but CR completion was (HR 0.43, 95% CI 0.31-0.61).

**Conclusion:** Automated referral in post-CABG patients resulted in modest improvement in CR program completion. Therefore, even when CR referral is automated to include all eligible patients, additional strategies to support CR program enrollment and completion remain necessary to achieve the desired health benefits.

standard discharge orders as systematic prompts, a discussion between clinicians and the patients regarding CR participation, and the receipt of the order by a CR program.<sup>9</sup>

Automated referral strategy has not been specifically investigated in post-CABG patients.<sup>10</sup> It is unclear whether automation is associated with CR completion rates. The present study objective was to assess rates of referral to and completion of CR after CABG, and whether automation is associated with CR referral and completion rates. We also examined how CR referral and program completion are related to survival benefits after CABG.

## Methods

### Data sources

The Alberta Provincial Project for Outcomes Assessment in Coronary Heart Disease (APPROACH) database provided demographic, clinical, and procedural information on all patients. APPROACH is a prospective registry enrolling all patients undergoing a cardiac catheterization or cardiac surgical procedure in Alberta, Canada.<sup>11</sup>

In Calgary, a single academic hospital (Foothills Medical Centre) provides cardiac surgical services, with all patients recovering on a single inpatient unit. CR service in Calgary has been provided since 1996 through a centralized program: TotalCardiology Rehabilitation. TotalCardiology Rehabilitation provides a comprehensive 12-week exercise-based CR program and has maintained a patient database since inception. The APPROACH and TotalCardiology Rehabilitation databases were linked through the use of the uniquely identifying Personal Health Numbers.

juillet 2007, les patients ayant subi un PAC sont systématiquement orientés vers un service de RC à leur sortie de l'hôpital. Nous avons utilisé une analyse des séries chronologiques interrompues pour évaluer l'incidence de cette orientation systématique vers un service de RC et les taux d'achèvement du programme de RC, et nous avons examiné l'association entre ces marqueurs du processus de RC et la mortalité.

**Résultats :** Au total, 8 118 patients ont subi un PAC durant la période étudiée : 5 103 patients avant l'orientation systématique vers un programme de RC et 3 015, après. Après l'adoption de l'orientation systématique, le taux d'orientation des patients est passé de 39,5 % à 75,0 % ( $p < 0,001$ ). L'orientation systématique a été associée à une hausse de 7,2 % de l'achèvement d'un programme de RC dans l'ensemble de la population (33,3 % vs 26,1 %;  $p < 0,001$ ). Dans les modèles ajustés, l'orientation vers un programme de RC seule n'a pas été associée à une baisse de la mortalité (rapport des risques instantanés [RRI] de 0,84; IC à 95 % : de 0,64 à 1,11), mais l'achèvement d'un tel programme l'a été (RRI de 0,43; IC à 95 % : de 0,31 à 0,61).

**Conclusion :** L'orientation systématique des patients ayant subi un PAC a entraîné une hausse modeste des taux d'achèvement d'un programme de RC. En conséquence, même lorsqu'une orientation systématique vers un programme de RC est instaurée afin d'inclure tous les patients admissibles, la mise en œuvre d'autres stratégies pour favoriser l'adhésion à un programme de RC et l'achèvement d'un tel programme s'impose afin d'obtenir les résultats escomptés en matière de santé.

## Study population

Patients from the Calgary Zone who underwent CABG from January 1, 1996, to March 31, 2016, were identified from the APPROACH database. Patients were excluded if they were under 18 years of age, did not have a valid Personal Health Number, or did not survive for at least 30 days after CABG surgery, because this would have precluded a CR referral.

## Intervention

Before July 2007, a referral to TotalCardiology Rehabilitation required a doctor's order. Thereafter, an automated referral strategy was implemented with the following components. First, the hospital's electronic medical record would automatically generate a referral form for eligible patients, which nursing staff were authorized to fax directly to TotalCardiology Rehabilitation without a doctor's order. Second, clinicians involved in the perioperative care—including nursing staff, physical therapists, nurse practitioners, and physicians—were encouraged to discuss CR participation with eligible patients.

## Outcomes of interest

The outcomes were CR referral, CR completion, and survival. Patients were considered to have been referred to CR if they had a referral recorded in TotalCardiology Rehabilitation database within 1 year after CABG surgery. Patients were considered to have completed CR if they completed both their baseline and their 12-week assessments. The rates of CR referral and completion before and after automation were compared. All-cause mortality was ascertained by quarterly

**Table 1. Baseline population characteristics before and after automation of cardiac rehabilitation referral**

Characteristic	Entire population (n = 8118)	Before automation (n = 5103)	After automation (n = 3015)	P value
Female (%)	1537 (18.9%)	991 (19.4%)	546 (18.1%)	0.15
Mean age (y)	65.4 ± 10.2	65.6 ± 10.0	65.0 ± 10.4	0.01
Hypertension	5560 (68.5%)	3356 (65.8%)	2204 (73.1%)	< 0.001
Hyperlipidemia	5623 (69.3%)	3484 (68.3%)	2139 (71.0%)	0.01
Diabetes mellitus	2461 (30.3%)	1452 (28.5%)	1009 (33.5%)	< 0.001
Family history (n = 7099)	1390 (19.6%)	433 (10.4%)	957 (32.5%)	< 0.001
Renal disease	323 (4.0%)	197 (3.9%)	126 (4.2%)	0.48
On dialysis	111 (1.4%)	79 (1.6%)	32 (1.1%)	0.07
Congestive heart failure	1182 (14.6%)	802 (15.7%)	380 (12.6%)	< 0.001
Cerebrovascular disease	661 (8.1%)	452 (8.9%)	208 (6.9%)	0.002
COPD	1241 (15.3%)	758 (14.9%)	483 (16.0%)	0.16
Current smoker	1826 (22.5%)	1177 (23.1%)	649 (21.5%)	0.11
Previous smoker	3248 (40.0%)	2253 (44.2%)	995 (33.0%)	< 0.001
Known malignancy	412 (5.1%)	262 (5.1%)	150 (5.0%)	0.75
GI or liver disease	638 (7.9%)	374 (7.3%)	264 (8.8%)	0.02
BMI (kg/m <sup>2</sup> ; n = 7142)	28.1 ± 5.2	27.9 ± 5.1	28.3 ± 5.4	< 0.001
Indication for catheterization				< 0.001
Stable angina	2898 (35.7%)	1743 (34.2%)	1155 (38.3%)	
Myocardial infarction	2406 (29.6%)	1458 (28.6%)	948 (31.4%)	
Unstable angina	1774 (21.9%)	1393 (27.3%)	381 (12.6%)	
Other	1040 (12.8%)	509 (10.0%)	531 (17.6%)	
Indication for CABG				< 0.001
1-vessel disease	707 (8.7%)	429 (8.4%)	278 (9.2%)	
2-vessel disease	1372 (16.9%)	908 (17.8%)	464 (15.4%)	
3-vessel disease	3656 (45.0%)	2373 (46.5%)	1283 (42.6%)	
Left main disease	2231 (27.5%)	1320 (25.9%)	911 (30.2%)	
Others	152 (1.9%)	73 (1.4%)	79 (2.6%)	

BMI, body mass index; CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; GI, gastrointestinal.

linkage with Alberta Vital Statistics up to March 31, 2017. For patients attending CR, we included death at any time after CR enrollment. To minimize immortal time bias, the follow-up for mortality in patients who were not referred or did not attend any session started 112 days after CABG, which was the median time from CABG to CR start.

### Statistical analysis

Baseline characteristics were compared between patients before and after automation, with the use of *t* test for continuous variables and  $\chi^2$  test for categoric variables. Crude proportions of CR referral rates before and after automation were compared with the use of *Z* tests. The temporal trends of the rates of CR referral and completion before and after automation were compared with the use of Wilcoxon signed-rank test.

An interrupted time series (ITS) analysis was undertaken to assess changes in the rates of CR referral and completion before and after automation.<sup>12,13</sup> The intervention point was the date of introduction of automated referral strategy (July 1, 2007). Referral rates were assessed in aggregated 6-month blocks before and after automation with the use of the ITS analysis module in Stata. To assess similarity between observations, autocorrelation was assessed with the use of the New-West approximation and a time lag was used as appropriate.

Logistic regression models were constructed to assess the predictors of CR referral in the entire cohort, and then separately in the pre- and postautomation groups. Likewise, the models predicting CR completion among the referred patients were constructed. The association between CR referral, completion, and survival was assessed with the use of Cox proportional hazard models. Patients were excluded from the survival model if they did not survive at least 196 days

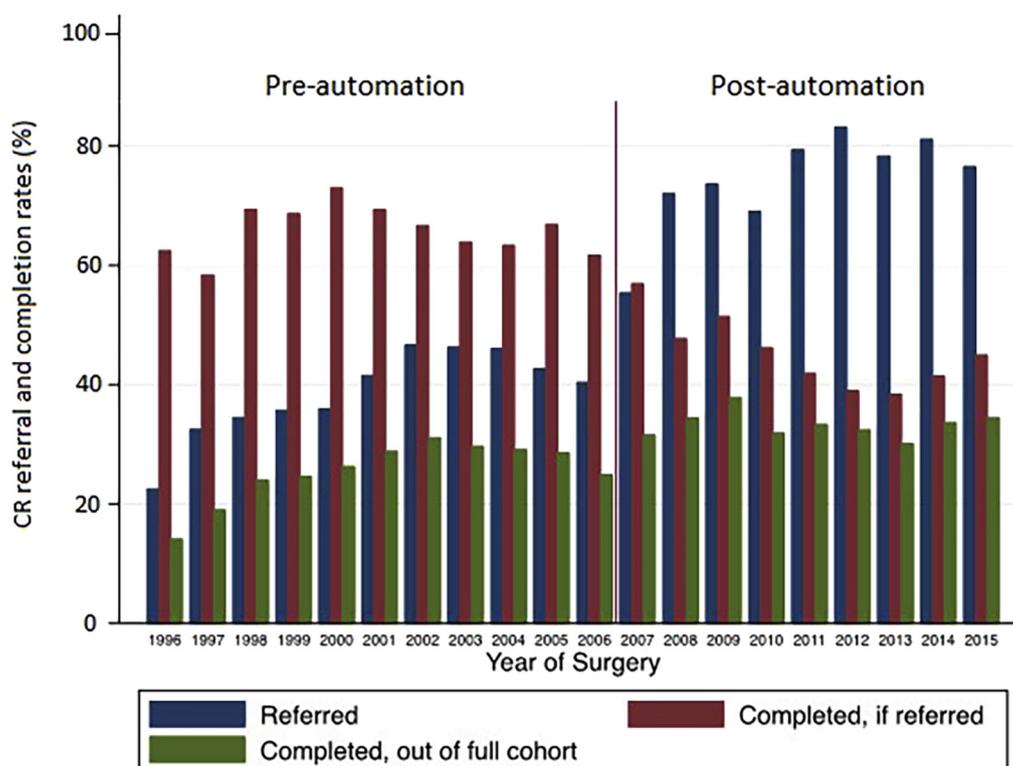
after CABG, ie, the median time from CABG to starting CR (112 days) plus the length of the CR program (84 days).

In the survival models, CR status was considered as a 3-level categoric variable: (1) not referred to CR; (2) referred to but did not complete CR; or (3) completed CR. For all survival models, the nonreferred group were the reference group. The models were adjusted for automation of referral, sex, age, year of surgery, coronary disease severity (defined according to the Duke Coronary Index), ejection fraction, hypertension, hyperlipidemia, diabetes mellitus (DM), chronic obstructive pulmonary disease (COPD), cerebrovascular disease, congestive heart failure (CHF), peripheral vascular disease, renal disease (serum creatinine > 177 mmol/L), dialysis, smoking, gastrointestinal disease, and presence of malignancy. The proportional hazards assumption was verified with the use of log-log plots. The initial survival model was assessed for interactions between automation and CR referral and completion. The models were then stratified by automation era. Survival rates were compared across categories of CR status (nonreferred, referred but not completed, and completed) with the use of log-rank tests. A 2-tailed value of *P* < 0.05 was defined as statistically significant.

All statistical analyses were conducted with the use of Stata 14. The study, including permission to link and analyze the data without individual patient consent, was approved by the Conjoint Health Ethics Review Board of the University of Calgary.

### Results

A total of 8,118 patients from the Calgary Zone, 1,537 (18.9%) of them female, underwent CABG surgery at the Foothills Medical Center from January 1, 1996, to March 31, 2016, and were eligible for a first referral to the CR program.



**Figure 1.** Yearly trends in rates of cardiac rehabilitation (CR) referral and completion. The vertical **solid red line** indicates implementation of the automated referral system.

Of those patients, 5,103 underwent surgery before automation and 3,015 after automation; 435 (5.4%) received combined CABG and valve replacement surgery. Patients before and after automation were similar in proportion female and prevalence of renal disease and COPD; however, patients before automation were more likely to have DM, hypertension, and hyperlipidemia (Table 1).

### Trends in rates of CR referral, attendance, and completion

From 1996 to 2016, there was an increase in referral rates, primarily related to the introduction of automation ( $P < 0.001$ ; Fig. 1). Referral rates nearly doubled with automation, from 39.5% before automation to 75.0% after automation (Fig. 1). Table 2 indicates that in the pre-automation era, 77.2% of referred patients were enrolled and 85.5% of those patients completed CR. In the post-automation era, 53.8% of referred patients were enrolled and 82.5% of those patients completed CR programs. Although patients after automation were overall more likely to complete CR (33.3% vs 26.1%;  $P < 0.001$ ), they were less likely to complete when the completers were considered as a

proportion of those referred (44.4% vs 66.0%;  $P < 0.001$ ; Fig. 1). This was primarily due to an increased proportion of referred patients that did not start CR after automation.

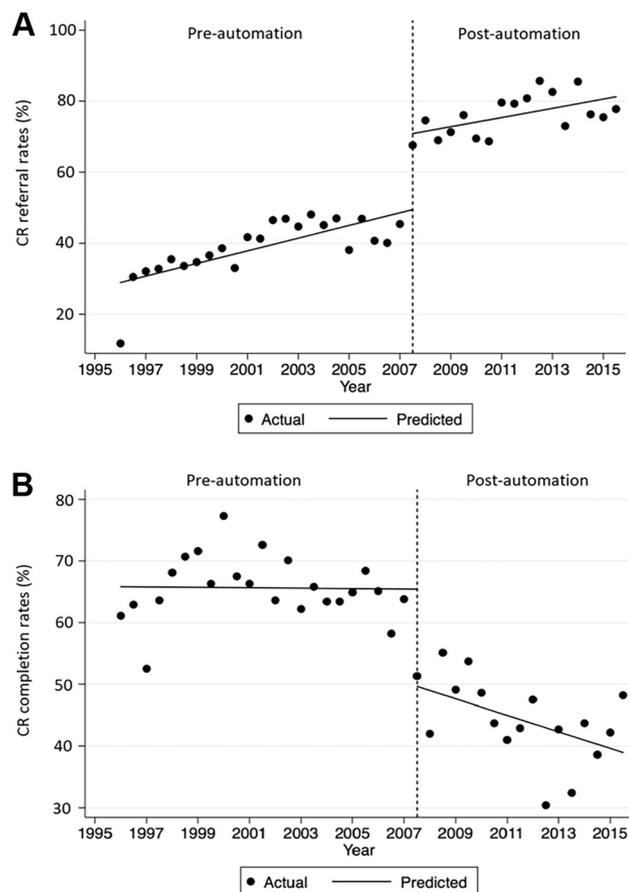
Over time there was a reduction in time from CABG to CR referral ( $P < 0.001$  for trend); in particular, from the pre- to postautomation era there was a reduction in median time from 55 days (interquartile range [IQR] 32–84 days) to 10 days (IQR 7–21 days;  $P < 0.001$ ). Likewise, there was a significant reduction in time from CR referral to CR enrollment over the 20-year study period ( $P < 0.001$ ), from a median of 81 days (IQR 52–133 days) to 63 days (IQR 51–84 days; Supplemental Figure S1).

### Interrupted time series analysis

Rates of CR referral and completion were compared before and after automation with the use of ITS analysis. Before automation, referral rates were increasing at 0.9% (absolute) per 6 months (95% CI 0.4%–1.4%;  $P = 0.001$ ). With automation, referral rates increased by 21.4% absolute (95% CI 14.6%–28.2%), indicating a significant immediate change with automation. Referral rates then remained flat ( $P = 0.45$ ; Fig. 2A). Among those referred, completion rates were flat

**Table 2.** Proportions of cardiac rehabilitation (CR) referral, enrollment, and completion

Variable	Entire population (n = 8118)	Before automation (n = 5103)	After automation (n = 3015)
Referred to CR	4277 (52.7%)	2015 (39.5%)	2262 (75.0%)
Referred to CR and enrolled	2774 (64.9%)	1556 (77.2%)	1218 (53.8%)
Enrolled and completed CR	2335 (84.2%)	1330 (85.5%)	1005 (82.5%)
Completed, among all patients	2335 (28.8%)	1330 (26.1%)	1005 (33.3%)



**Figure 2.** (A) Changes in cardiac rehabilitation (CR) referral rates before and after automation of referral. (B) Changes in CR completion rates before and after automation of referral, among referred patients. The vertical **dashed line** indicates of implementation of the automated referral system.

before and after automation ( $P$  for trend = 0.93 before automation;  $P = 0.07$  after automation). However, the automation itself was associated with a 15.8% (95% CI 9.7%–21.8%;  $P < 0.001$ ) drop in completion rates among those referred (Fig. 2B).

### Referral

In the logistic regression model, the odds ratio (OR) of CR referral was 2.81 (95% CI 2.36–3.47) between the pre-automation and postautomation eras (Table 3). Younger age at surgery, later year of surgery, male sex, and hyperlipidemia were associated with higher likelihood of referral; peripheral vascular disease, dialysis, smoking, DM, and CHF were associated with lower likelihood. When models were stratified into pre- and postautomation groups, later year of surgery, age at surgery, peripheral vascular disease, smoking, and DM were no longer associated with the likelihood of referral after automation (Supplemental Table S1). However, male sex and hyperlipidemia still predicted increased likelihood of referral, and dialysis and CHF still predicted the failure to be referred.

### Program completion

In the logistic regression model, automation of CR referral predicted CR noncompletion (OR 0.56, 95% CI 0.43–0.72), as did later year of surgery, advanced age, female sex, and several other comorbidities (Table 3). In both the pre- and postautomation eras, times from CABG to CR referral were longer in those patients who did not complete CR (before automation: 62 days [IQR 42–93 days] in noncompleters vs 53 days [IQR 37–77 days] in completers [ $P < 0.001$ ]; after automation: 11 days [IQR 7–22 days] vs 8 days [IQR 7–19 days];  $P < 0.001$ ). The predictors of CR completion were similar between the pre- and postautomation eras, with the exception of time from CABG to CR referral and later year of surgery; before automation, delay in CABG to CR referral was associated with lower likelihood of CR completion, and after automation, later year of surgery predicted lower likelihood of CR completion (Supplemental Table S2).

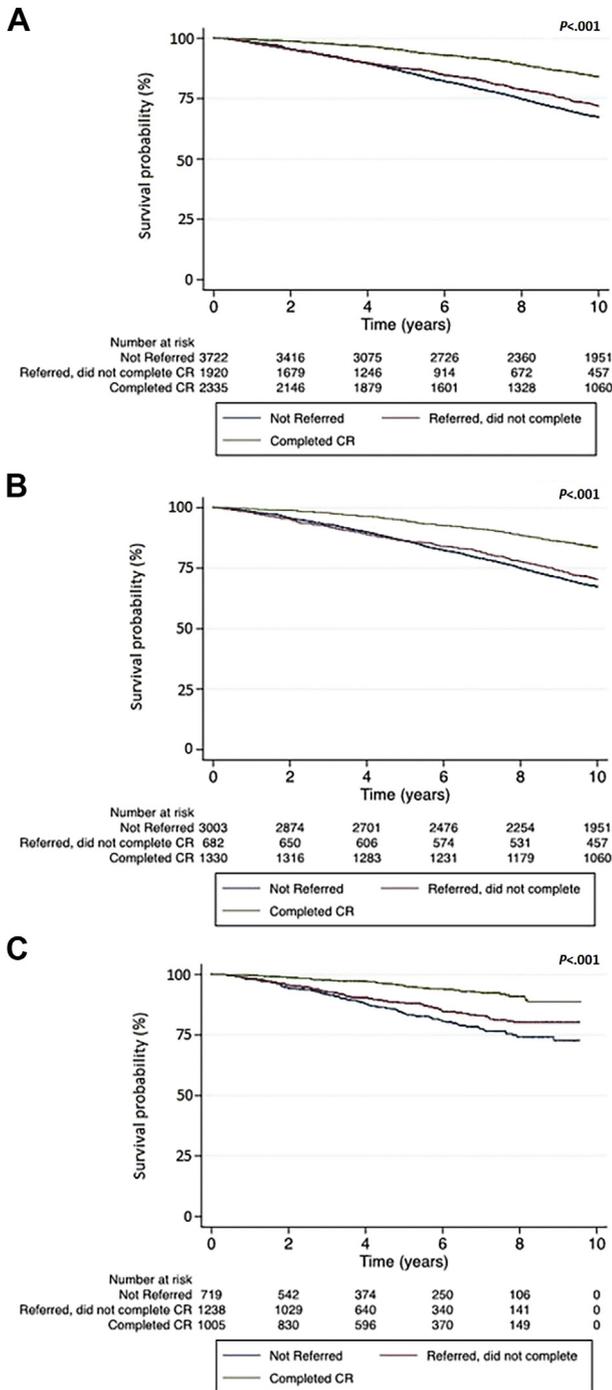
### Long-term survival

One hundred forty-one patients died within 196 days after CABG surgery and were excluded from the survival analysis. The median follow-up time for patients included in the survival analysis was 8.8 years (IQR 4.4–13.4 years); there were 2,504 deaths. Survival rate was significantly better in subjects who completed a CR program in the overall cohort (Fig. 3A), as well as within the separate pre- and postautomation cohorts (Fig. 3, B and C). Survival rate at 10 years was 67.4% in those who were not referred to CR, 72.0% in those who were referred to but did not complete CR, and 84.2% in those who completed CR. In the Cox proportional hazards model including the entire population, CR referral was not associated with any survival benefit (hazard ratio [HR] 0.84, 95% CI 0.64–1.11), but CR completion was (HR 0.43, 95% CI 0.31–0.61). In the Cox model, there was a significant

**Table 3.** Multivariable predictors of cardiac rehabilitation (CR) referral and completion

Predictor	OR (95% CI) of CR referral among entire population	OR (95% CI) of CR completion among referred patients
Automation	2.81 (2.36, 3.47)	0.56 (0.43, 0.72)
Year of surgery	1.05 (1.04, 1.07)	0.96 (0.94, 0.99)
Time from CABG to referral (d)		0.999 (0.997, 1.000)*
Age (y)		
< 40	2.25 (1.20, 4.19)	1.13 (0.62, 2.07)
40–49.9	Reference	Reference
50–59.9	0.97 (0.79, 1.20)	1.22 (0.94, 1.59)
60–69.9	0.69 (0.56, 0.85)	1.03 (0.80, 1.34)
70–79.9	0.53 (0.43, 0.65)	0.79 (0.60, 1.03)
≥ 80	0.34 (0.26, 0.46)	0.38 (0.25, 0.57)
Peripheral vascular disease	0.78 (0.66, 0.92)	0.73 (0.57, 0.93)
Sex (male)	1.45 (1.28, 1.65)	1.55 (1.30, 1.85)
Dialysis	0.42 (0.25, 0.69)	0.35 (0.15, 0.84)
Current smoker	0.82 (0.72, 0.92)	0.51 (0.44, 0.60)
Diabetes mellitus	0.83 (0.75, 0.92)	0.70 (0.61, 0.81)
Cerebrovascular disease	NS	0.72 (0.56, 0.93)
Congestive heart failure	0.86 (0.74, 0.996)	0.65 (0.53, 0.79)
Hyperlipidemia	1.24 (1.12, 1.38)	1.21 (1.04, 1.39)

CABG, coronary artery bypass grafting; CI, confidence limits.  
\*  $P = 0.06$ .



**Figure 3.** Unadjusted Kaplan-Meier curves comparing survival rates according to cardiac rehabilitation (CR) referral and completion status: (A) entire population; (B) before automation of referral; (C) after automation of referral.

interaction between automation and CR completion in terms of survival, in that the benefit derived from CR completion was higher after automation. The models were then stratified by automation era. In multivariable models, CR completion was associated with improved survival before automation (HR 0.73, 95% CI 0.65-0.81) and after automation (HR 0.39, 95% CI 0.28-0.55).

**Discussion**

In this analysis of a large post-CABG cohort with long-term follow-up, we found that the automation of CR referral was associated with a near doubling in the proportion of patients referred to CR, but with a more modest increase in overall CR completion. Furthermore, CR completion, but not CR referral, was associated with improved survival.

CR referral and program completion are 2 critical steps in the CR service delivery. CR referral is generally dependent on clinician-oriented factors, whereas CR program completion is more dependent on patient-oriented factors.<sup>14</sup> In the present study, the automation almost doubled CR referrals, from 39.5% to 75.0%. However, this substantial increase in referrals did not translate into meeting the 85% referral goal set by Canadian Cardiovascular Society.<sup>14</sup> The large increase in referrals was associated with only a modest 7% increase in the overall proportion of patients completing CR. This suggests that for many of the previously nonreferred patients that were referred to CR through automation, additional barriers to program enrollment and completion remain. Simply instituting an automated referral process without, among other factors, a program mandating strong endorsement of CR participation by health care providers does not significantly improve the proportion of eligible patients completing CR.<sup>15</sup> One such promising strategy is designating a CR “liaison”<sup>16</sup> who is responsible for leading a discussion on the importance of CR between health care providers and eligible patients and for disseminating materials. The liaison strategy has been shown to augment CR attendance.<sup>17</sup> A prospective trial of CAD patients evaluated the effectiveness of 3 referral strategies: automated referral only, liaison only, and a combined approach.<sup>10</sup> These referral strategies attained referral rates of 70.2%, 59%, and 85.8%, respectively, suggesting that combining automated referral with liaison may be particularly effective. The automation of referral used in our study included encouraging clinicians to promote CR to patients after CABG rather than a formal liaison strategy. We speculate that a liaison strategy, combining specific counselling supplemented by patient education materials reinforcing the importance of CR, could further improve the CR completion rates.

CR completion may be particularly important in post-CABG patients. Compared with patients receiving percutaneous coronary intervention, post-CABG patients typically have more complex coronary anatomy and are more likely to have left ventricular dysfunction.<sup>18</sup> They are also more likely to engage in unhealthy behaviors, such as smoking and sedentary lifestyle choices, and to have a higher burden of comorbidities, such as DM, before the CABG procedure. Given their higher risk profile, post-CABG patients could theoretically benefit more from completing a CR program. Furthermore, post-CABG patients are less likely to remain adherent to medications and to visit a cardiologist for subsequent care than those undergoing percutaneous coronary intervention.<sup>19-21</sup> CR programs provide opportunities for early follow-up to ensure that patients have the appropriate prescriptions, are taking their medications as prescribed, and are educated about the nature of their disease and the need for long-term secondary prevention.

The present study also indicated that longer wait time for a CR referral in the preautomation era was associated with lower

likelihood of CR completion. This is consistent with the work of Marzolini et al.,<sup>22</sup> who also demonstrated lower completion rates with longer wait time, and our earlier work with ST-segment-elevation myocardial infarction patients.<sup>23</sup> More importantly, both studies also reported that longer wait time was associated with less improvement in cardiopulmonary fitness and heart rate recovery, which are critical predictors of long-term survival. In the present study, we think that the combination of automated referral with gradually decreasing CR wait time may be responsible for the increasing overall proportion of CR program completion. Other modifications could be adopted to engage referred patients even sooner and improve CR completion. For example, patients could begin nonexercise CR components before exercise, or they could be encouraged to participate in more gentle exercise before a full CR program, which a small study from the Mayo Clinic demonstrated to be safe.<sup>24</sup>

In clinical practice, CR attendance and completion are important determinants of morbidity and mortality.<sup>25</sup> In the present study, CR completion predicted survival benefits. Our previous study also demonstrated that there is a dose-response relationship between CR session attendance and mortality.<sup>25</sup> However, increasing CR referral rate alone is inadequate to improve the prognosis, because higher referral rates do not automatically improve CR attendance and completion rates.<sup>26</sup> Mazzini et al. reported that only 34% of referred patients were enrolled in CR programs.<sup>27</sup> Therefore, efforts focusing on the automated referral alone may fall short.

In addition to automating the CR referral process, other systematic referral strategies, such as designating a CR liaison, motivational interviewing, and motivational letters and incentives, could be incorporated into the CR process from initial referral through enrollment and up to program completion.<sup>9</sup> To address conventional facility-based CR accessibility barriers, such as transportation challenges, scheduling conflicts, and functional impairments, alternate CR models are needed. Home-, community-, and internet-based CR models have the potential to significantly improve attendance and outcomes, particularly in older adults, women, diverse ethnic groups, low-income populations, and others who are challenged by accessibility barriers.<sup>28</sup>

This study has several limitations. First, automation of referral was brought in as a policy change, and the study assessed practice patterns simply before and after automation rather than as a randomized trial of the changes in CR referral practice. We therefore cannot claim causality of our observed associations. However, the results of the ITS analysis suggested that the increased CR referral rate after automation was unlikely to be due to secular trends in CR referral patterns. Second, the automated CR referral process still required human intervention, with the result that not all eligible patients were referred, for unknown reasons. Third, the information on which patient was truly eligible for CR before and after automation was not included in our database, so we could not describe the proportion of this group of patients. Fourth, our database did not include information on completeness of revascularization, other CABG-related details, and secondary prevention medications. Therefore, it was impossible to adjust for these variables in the analysis. Fifth, we were not able to study the impact of cardiopulmonary fitness level on the CR referral, enrollment, and completion patterns, because this

information was not available for all patients. Finally, the study did not account for all socioeconomic and psychological factors known to be associated with CR completion.

## Conclusion

Automation of CR referral for post-CABG patients resulted in higher CR referral rates but only modest improvement in CR program completion. Therefore, even when CR referral is automated to include all eligible patients, additional strategies to support CR program enrollment and completion remain necessary to achieve the desired health benefits.

## Acknowledgements

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## Disclosures

The authors have no conflicts of interest to disclose.

## References

1. Hawkes AL, Nowak M, Bidstrup B, Speare R. Outcomes of coronary artery bypass graft surgery. *Vasc Health Risk Manag* 2006;2:477-84.
2. Parang P, Arora R. Coronary vein graft disease: pathogenesis and prevention. *Can J Cardiol* 2009;25:e57-62.
3. Kulik A, Ruel M, Jneid H, et al. Secondary prevention after coronary artery bypass graft surgery: a scientific statement from the American Heart Association. *Circulation* 2015;131:927-64.
4. Kachur S, Chongthammakun V, Lavie CJ, et al. Impact of cardiac rehabilitation and exercise training programs in coronary heart disease. *Prog Cardiovasc Dis* 2017;60:103-14.
5. Pack QR, Goel K, Lahr BD, et al. Participation in cardiac rehabilitation and survival after coronary artery bypass graft surgery: a community-based study. *Circulation* 2013;128:590-7.
6. Bittner V, Sanderson B, Breland J, Green D. Referral patterns to a University-based cardiac rehabilitation program. *Am J Cardiol* 1999;83:252-5.
7. Niebauer J. Is there a role for cardiac rehabilitation after coronary artery bypass grafting? Treatment after coronary artery bypass surgery remains incomplete without rehabilitation. *Circulation* 2016;133:2529-37.
8. Thomas RJ, Balady G, Banka G, et al. 2018 ACC/AHA clinical performance and quality measures for cardiac rehabilitation. A report of the American College of Cardiology/American Heart Association Task Force on Performance Measures. *J Am Coll Cardiol* 2018;71:1814-37.
9. Ades PA, Keteyian SJ, Wright JS, et al. Increasing cardiac rehabilitation participation from 20% to 70%: a road map from the Million Hearts Cardiac Rehabilitation Collaborative. *Mayo Clin Proc* 2017;92:234-42.
10. Grace SL, Russell KL, Reid RD, et al. Effect of cardiac rehabilitation referral strategies on utilization rates: a prospective, controlled study. *Arch Intern Med* 2011;171:235-41.

11. Ghali WA, Knudtson ML; APPROACH Investigators. Overview of the Alberta Provincial Project for Outcome Assessment in Coronary Heart Disease. *Can J Cardiol* 2000;16:1225-30.
12. Linden A. Conducting interrupted time-series analysis for single- and multiple-group comparisons. *Stata J* 2015;15:480-500.
13. Bond SE, Chubaty AJ, Adhikari S, et al. Outcomes of multisite antimicrobial stewardship programme implementation with a shared clinical decision support system. *J Antimicrob Chemother* 2017;72:2110-8.
14. Grace SL, Turk-Adawi K, Santiago de Araújo Pio C, Alter DA. Ensuring cardiac rehabilitation access for the majority of those in need: a call to action for Canada. *Can J Cardiol* 2016;32:S358-64.
15. Fletcher GF, Landolfo C, Niebauer J, et al. Promoting physical activity and exercise: JACC health promotion series. *J Am Coll Cardiol* 2018;72:1622-39.
16. Grace SL, Krepostman S, Brooks D, et al. Referral to and discharge from cardiac rehabilitation: key informant views on continuity of care. *J Eval Clin Pract* 2006;12:155-63.
17. Grace SL, Chessex C, Arthur H, et al. Systematizing inpatient referral to cardiac rehabilitation 2010: Canadian Association of Cardiac Rehabilitation and Canadian Cardiovascular Society joint position paper endorsed by the Cardiac Care Network of Ontario. *Can J Cardiol* 2011;27:192-9.
18. Deb S, Wijeyesundera HC, Ko DT, et al. Coronary artery bypass graft surgery vs percutaneous interventions in coronary revascularization: a systematic review. *JAMA* 2013;310:2086-95.
19. Hlatky MA, Solomon MD, Shilane D, et al. Use of medications for secondary prevention after coronary bypass surgery compared with percutaneous coronary intervention. *J Am Coll Cardiol* 2013;61:295-301.
20. Eagle KA, Kline-Rogers E, Goodman SG, et al. Adherence to evidence-based therapies after discharge for acute coronary syndromes: an ongoing prospective, observational study. *Am J Med* 2004;117:73-81.
21. Go AS, Rao RK, Dauterman KW, Massie BM. A systematic review of the effects of physician specialty on the treatment of coronary disease and heart failure in the United States. *Am J Med* 2000;108:216-26.
22. Marzolini S, Blanchard C, Alter DA, Grace SL, Oh PI. Delays in referral and enrolment are associated with mitigated benefits of cardiac rehabilitation after coronary artery bypass surgery. *Circ Cardiovasc Qual Outcomes* 2015;8:608-20.
23. Parker K, Stone JA, Arena R, et al. An early cardiac access clinic significantly improves cardiac rehabilitation participation and completion rates in low-risk ST-elevation myocardial infarction patients. *Can J Cardiol* 2011;27:619-27.
24. Pack QR, Dudycha KJ, Roschen KP, Thomas RJ, Squires RW. Safety of early enrollment into outpatient cardiac rehabilitation after open heart surgery. *Am J Cardiol* 2015;115:548-52.
25. Martin BJ, Hauer T, Arena R, et al. Cardiac rehabilitation attendance and outcomes in coronary artery disease patients. *Circulation* 2012;126:677-87.
26. Boyden T, Rubenfire M, Franklin B. Will increasing referral to cardiac rehabilitation improve participation? *Prev Cardiol* 2010;13:192-201.
27. Mazzini MJ, Stevens GR, Whalen D, Ozonoff A, Balady GJ. Effect of an American Heart Association Get With the Guidelines program-based clinical pathway on referral and enrollment into cardiac rehabilitation after acute myocardial infarction. *Am J Cardiol* 2008;101:1084-7.
28. Lavie CJ, Kachur S, Milani RV. Making cardiac rehabilitation more available and affordable. *Heart* 2019;105:94-5.

### Supplementary Material

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