Original Article

Computerized Electronic Order Set: Use and Outcomes for Heart Failure Following Hospitalization

Robert J.H. Miller, MD,^a Alexandra Bell, MD,^a Sandeep Aggarwal, MD,^a James Eisner, MD,^b and Jonathan G. Howlett, MD^a

^a Libin Cardiovascular Institute, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada

^b Alberta Health Services, Calgary, Alberta, Canada

ABSTRACT

Background: Quality improvement initiatives improve health care delivery but may be resource intensive and disrupt clinical care. An embedded heart failure order set (HFOS) within a computerized physician order-entry system may mitigate these concerns.

Methods: An HFOS, based on proven interventions, was implemented within an existing computerized physician order-entry system in all adult acute-care hospitals in a single Canadian metropolitan city and interrogated between January 1, 2013 and December 31, 2015. The composite of repeat hospitalization or death within 30 days of hospital discharge and hospital length of stay were reported.

Results: In total, 8969 patients were included with mean age 75.6 ± 13.5 years; 4673 (52.1%) were male. The HFOS was used in 731 (8.2%) patients. After analysis of 724 pairs of propensity-score

RÉSUMÉ

Contexte : Les initiatives visant à l'amélioration de la qualité favorisent la prestation des soins de santé, mais elles peuvent nécessiter beaucoup de ressources et perturber les soins cliniques. Un ensemble d'ordonnances relatives à l'insuffisance cardiaque (HFOS pour *heart failure order set*) intégré dans un système informatisé de saisie des ordonnances des médecins pourrait atténuer ces préoccupations.

Méthodes : Un HFOS, basé sur des interventions éprouvées, a été mis en place au sein d'un système informatisé de saisie d'ordonnances médicales existant dans tous les hôpitaux de soins actifs pour adultes d'une même métropole canadienne et a été interrogé entre le 1^{er} janvier 2013 et le 31 décembre 2015. Les données combinées de réadmission ou de décès pour les 30 jours suivant la sortie de l'hôpital et la durée du séjour à l'hôpital ont été répertoriées.

Heart failure (HF) accounts for an estimated prevalence of 3% among Canadians over age 40 years.¹ Persons with HF are characterized by suboptimal use of guideline-recommended therapies, and frequent hospitalizations.^{2–5} Although nearly 90% will survive to hospital discharge, repeat hospitalization within 30 days will occur in over 20%.³ Several innovative tools and procedures have been developed to improve adoption of best treatment practices for patients admitted to the hospital with HF.^{6–9} In particular, multiple complementary interventions may yield substantial improvements in postdischarge outcomes.^{10,11}

More recently, use of order sets and clinical decision support systems, primarily paper-based systems, has been shown to improve physician adherence to evidence-based care.^{6,12,13}

Although an expanding number of electronic medical record (EMR) solutions are used in Canadian health care centres, little evidence is available on their subsequent impact on patient outcomes, particularly in the context of a computerized physician order-entry system (CPOES).¹⁴ In a study based in the United States, Krive et al. demonstrated lower in-hospital mortality in a cohort of 719 patients managed with an electronic HF order set (HFOS).¹³ However, they did not account for patient factors that may have influenced the decision to use the order set.

We hypothesized that use of an HF-focused CPOES at patient admission for HF would be associated with improved outcomes. To test this hypothesis, we retrospectively assessed the clinical impact of utilization of an electronic HFOS in patients admitted with HF.

Methods

Study setting

Alberta Health Services is the publicly funded, sole inpatient health care provider in the province of Alberta, Canada. At the time of the study, the Calgary Zone of Alberta Health

Received for publication June 1, 2020. Accepted June 17, 2020.

Ethics Statement: The study was approved by the University of Calgary Research Ethics Committee, file number REB14_0507.

Corresponding author: Dr Jonathan G. Howlett, Room C-838, 1403 29th Street NW, Calgary, Alberta, T2N 2Y9, Canada. Tel: +1-403-944-3232; fax: +1-403-944-3262.

E-mail: howlettjonathan@gmail.com

See page 504 for disclosure information.

matched cohorts, patients with HFOS use experienced a lower median length of stay (8.6 vs 9.4 days, $P = 0.016$) and a trend toward lower composite repeat hospitalization or death (14.5% vs 17.7%, $P = 0.115$, hazard ratio 0.79 (0.60–1.05). Patients with HFOS use were more likely to undergo a test for left ventricular ejection fraction (88.6% vs 76.7%, $P < 0.001$, and to be referred to a heart failure clinic (48.5% vs 6.3%), with similar rates of discharge prescription of beta-blockers (88.7% vs 86.3) and angiotensin-converting enzyme inhibitors (87.4% vs 89.0%).

Conclusions: Use of a designated HFOS within a computerized physician order-entry system is associated with shorter hospital length of stay without increase in deaths or readmissions. These findings should be confirmed in a prospective controlled trial.

Services included 3 adult acute-care hospitals, which provided community and tertiary care to an approximate 2.4 million people in the greater Calgary area, as well as to southern Alberta. All acute-care centres use the Sunrise Clinical Manager (SCM; Eclipsis Corporation, Boca Raton, FL), an electronic medical record (EMR) with CPOES functionality, for result viewing as well as all order entry, including admission orders, medications, investigations, and care needs. The study was approved by the University of Calgary Institutional Review Board.

Intervention

Between November 2008 and September 2009, a multi-disciplinary group within the Calgary zone was charged with development and implementation of an HF optimization program. This was an evidence-based set of 11 interventions designed to ensure the use of best practices for hospital inpatients (Supplemental Table S1).^{11,14,15} These interventions were based on recommendations of the 2008 Canadian Cardiovascular Society Heart Failure Guidelines Focused Update concerning the transition from hospital to home.¹⁵ The central intervention, the electronic HFOS (which included prechecked orders for evidence-based medications for HF—angiotensin-converting enzyme inhibitors, angiotensin receptor antagonists, beta blockers, diuretics, mineralocorticoid receptor antagonists, oral anticoagulants) was created as one of the interventions and contained prechecked orders for the other 10 interventions. Medication reconciliation was not included, as this was the focus of a preexisting initiative.

Order set implementation began July 2009, initially at the largest hospital, in wards serving a high volume of patients admitted with HF. It became available at all sites by January 2010. Typing “Heart Failure Admission,” “CHF” (for congestive HF), or variations thereof into the EMR dialog box allowed access to the order set at the time of hospital admission or at any point during the hospital stay. Health care

Résultats : Au total, 8 969 patients ont été inclus avec un âge moyen de $75,6 \pm 13,5$ ans ; 4 673 (52,1 %) étaient des hommes. Le HFOS a été utilisé pour 731 (8,2 %) patients. Après analyse de 724 paires de cohortes appariées par score de propension, les patients associés à l'usage du HFOS ont connu une durée médiane de séjour hospitalier plus faible (8,6 contre 9,4 jours, $p = 0.016$) et une tendance combinée de réadmission ou de décès plus faible (14,5 % contre 17,7 %, $p = 0,115$, rapport de risque 0,79 (0,60-1,05). Les patients associés à l'usage du HFOS étaient plus susceptibles de subir un examen pour mesurer leur fraction d'éjection ventriculaire gauche (88,6 % contre 76,7 %, $p < 0,001$, et d'être orientés vers une clinique d'insuffisance cardiaque (48,5 % contre 6,3 %), avec des taux similaires de prescription à la sortie de bêta-bloquants (88,7 % contre 86,3 %) et d'inhibiteurs de l'enzyme de conversion de l'angiotensine (87,4 % contre 89,0 %).

Conclusions : L'utilisation d'un HFOS particulier dans un système informatisé de saisie d'ordonnances médicales est associée à une réduction de la durée du séjour hospitalier sans augmentation des décès ou des réadmissions. Ces résultats devraient être confirmés dans le cadre d'un essai comparatif prospectif.

providers were informed of the availability of this HFOS via scheduled e-mails from the Information Technology Department. Additionally, the development team members provided lectures to the Internal Medicine, Cardiology, and Hospitalist Services group. Paper notifications were posted on the floors of interest (where 50%–60% of HF patients were admitted), and reminders were incorporated as the screensavers on hospital computers. Finally, unit managers were included in the rollout, and “in-service” sessions were scheduled for staff on at least 2 occasions per floor, with repeat staff meetings to reinforce awareness whenever the monthly compliance rate with daily weight measurements fell below 80%. Compliance with daily weights was defined as the number of days on which weight was documented divided by the number of days in the hospital, for all patients with HF. Between 2010 and 2013, active maintenance of these interventions was not performed. Ultimately, however, use of the order set remained a clinical decision and was left to the most responsible physician in each case and was not randomized.

Study population

Patients admitted with a primary or secondary diagnosis of HF between January 1, 2013 and December 31, 2015 were included. All admitting diagnoses were entered into the EMR at the time of admission by the admitting physician and subsequently coded by trained health record personnel in accordance with the International Classifications of Diseases (ICD) 10.¹⁶ Patients were considered to have HF during hospitalization if any codes for HF (ICD 150.x) were listed as primary or secondary diagnoses. Patients under 18 years of age were excluded ($n = 118$), as were patients on dialysis ($n = 35$). Patients on renal replacement therapy were excluded because HF admissions may be related to insufficient volume removal during dialysis and a less-developed rationale for HF pharmacotherapy. None of the patients were managed with the HFOS. Only the first hospitalization was included

for each patient ($n = 6837$ repeat hospitalizations excluded). Cases were included in the HFOS use group if the order set was activated for that patient at any time during hospitalization.

Data collection and availability

Documented variables from the EMR included patient age and sex, vital signs on admission, treating physician type, and completion of a cardiologist consultation. Prescription of medications at hospital discharge was also included. Comorbid conditions were determined from discharge diagnoses using previously described ICD-10 coding.¹⁷ In all, 36 variables were included for analysis (Supplemental Table S2). In an audit of 100 cases, we determined that comorbid conditions were abstracted completely in 73 cases, which was consistent with the previously known completion rate.¹⁸ The Charlson Comorbidity Index was calculated as previously described.¹⁹

The first recorded laboratory values for each patient were extracted automatically from the EMR, with missing values for levels of sodium ($n = 47$), creatinine ($n = 50$), hemoglobin ($n = 50$), and white blood cells ($n = 50$) imputed with the population mean value.

Outcomes

The primary outcome was the composite of death and repeat HF hospitalization at 30 days following hospital discharge. Postdischarge outcomes were tracked by linking data from the Sunrise Clinical Manager to the province-wide discharge and admission database (DAD) and vital statistics registry, which include all hospitalizations and deaths for Alberta residents, respectively. Only the first rehospitalization within 30 days was considered for patients with multiple rehospitalizations.

Ancillary measures included use of angiotensin-converting enzyme (ACE) inhibitors/angiotensin receptor blockers and beta-blockers at admission and discharge. Assessment of left ventricular ejection fraction with any modality (echocardiography, radionuclide angiography, cardiac catheterization, or cardiac magnetic imaging) while in the hospital was also recorded. The remaining interventions listed in Supplemental Table S1 were not documented in the EMR and therefore were not included as outcomes.

Statistical analysis

Continuous variables were summarized as mean $\pm$ standard deviation and compared with a Student t test or Wilcoxon rank-sum test as appropriate. Categorical variables were summarized as number (proportion) and compared with a χ^2 or Fisher exact test, as appropriate.

To account for selection bias related to the clinical (non-randomized) decision to use the HFOS, we performed a propensity-score matching analysis. Patients who were not managed with the HFOS were matched to patients managed with the HFOS using 1:1 nearest-neighbor matching, with a caliper of 0.001. The propensity score included the following: year; age; sex; past medical history; admission systolic blood pressure and heart rate; levels of serum creatinine, blood urea

nitrogen, serum sodium, and glucose; involvement of cardiology; and medical therapy at admission. Components of the propensity score and their weights are shown in Supplemental Table S3. Distribution of the propensity score in patients who were managed with vs without the HFOS are shown in Supplemental Figure S1. Propensity-score matching was repeated after excluding all patients with > 30 -day length-of-stay (LOS; termed “limited propensity match” cohort). Matched groups were compared with standardized mean differences, with a difference of > 0.10 considered significant.

Associations with clinical outcomes (LOS, 30-day readmission, 30-day all-cause mortality, and a composite of death and rehospitalization at 30 days) were assessed in the overall cohort, the propensity-score matched cohort, and the limited propensity-score matched cohort. Associations with hospital LOS were assessed with ordinal logistic regression. Postdischarge outcomes were assessed only in patients who survived to discharge.

All statistical tests were 2-sided, with $P < 0.05$ considered significant. All analyses were performed with STATA version 13 (StataCorp, College Station, TX).

Results

Population characteristics

In total, 8969 patients were included in our study with a mean age of 75.6 ± 13.5 years; 4673 (52.1%) were male. The HFOS was used in 731 (8.2%) patients, with characteristics for the 2 groups shown in Table 1. Patients managed with the HFOS were younger (mean age 74.5 vs 75.6 years, $P = 0.015$) and more likely to have cardiology as an attending or consulting service (77.8% vs 68.3%, $P < 0.001$). The mean Charlson Comorbidity Index was also lower in patients managed with the HFOS (4.7 vs 5.0, $P < 0.001$).

Details of the propensity-score matched cohorts are shown in Table 2. After propensity-score matching, there were no significant residual differences between groups, with both similar mean age (74.6 vs 74.6 years, $P = 0.983$) and proportion of patients having cardiology as an attending or consulting service (77.6% vs 76.7%, $P = 0.707$). The mean Charlson Comorbidity Index was also similar in patients managed with vs without the HFOS (4.7 vs 4.7, $P = 0.842$).

Inpatient management

Summary of the inpatient management of patients managed with vs without the HFOS in the overall and propensity-score matched cohort are shown in Figure 1. In the overall cohort, patients managed with the HFOS were more likely to have a weight measured on more than 50% of days (94.3% vs 61.6%, $P < 0.001$), have a measurement of left ventricular ejection fraction (LVEF; 88.3% vs 74.6%, $P < 0.001$), and be discharged on a beta-blocker (88.7 vs 76.4%, $P < 0.001$) and an ACE inhibitor (87.4% vs 77.2%, $P < 0.001$). Patients managed with the HFOS were also more likely to be referred to a multidisciplinary HF clinic (48.4% vs 5.2%, $P < 0.001$).

In the propensity-score matched cohort, patients managed with the HFOS were more likely to have a weight measured

Table 1. Baseline demographic and clinical characteristics

Characteristic	Order set (n = 731)	No order set (n = 8238)	P
Age (y)	74.5 ± 13.5	75.6 ± 13.5	0.015
Male	395 (54.0)	4278 (51.9)	0.280
Cardiologist attending/consulting	569 (77.8)	5623 (68.3)	< 0.001
Past medical history			
Coronary artery disease	146 (20.0)	1574 (19.1)	0.557
Atrial fibrillation	251 (34.3)	2715 (33)	0.460
Hypertension	372 (50.9)	4249 (51.6)	0.728
Diabetes mellitus	251 (34.3)	2593 (31.5)	0.115
Peripheral vascular disease	10 (1.4)	184 (2.2)	0.213
Cerebrovascular disease	10 (1.4)	260 (3.2)	0.004
Chronic kidney disease	114 (15.6)	1290 (15.7)	1.000
COPD	102 (14.0)	1660 (20.2)	< 0.001
Liver disease	79 (10.8)	964 (11.7)	0.508
Malignancy	29 (4.0)	578 (7.0)	0.001
Dementia	18 (3.7)	517 (8.7)	< 0.001
Charlson Comorbidity Index	4.7 ± 1.6	5.0 ± 1.6	< 0.001
Charlson Comorbidity Index, median (IQR)	5 (4–6)	5 (4–6)	< 0.001
Systolic BP (mm Hg)	126.7 ± 21	126.4 ± 21.5	0.704
Heart rate (bpm)	82.4 ± 19.4	82.4 ± 18.8	0.156
Creatinine (µmol/L)	125 ± 83	130 ± 116	0.279
Sodium (mmol/L)	137 ± 5	136 ± 5	0.036
Hemoglobin (g/L)	123 ± 21	120 ± 22	< 0.001
WBC (×10 ⁹ /L)	8.8 ± 3.7	10.5 ± 14.5	0.002
Admission medications			
Beta-blocker	566 (77.4)	5073 (61.6)	< 0.001
ACE inhibitor/ARB	579 (79.2)	4946 (60.0)	< 0.001

Values are n (%) or mean ± standard deviation, unless otherwise indicated. Daily weights expressed as a percentage of available days in the hospital, including day of discharge. ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker; BP, blood pressure; bpm, beats per minute; COPD, chronic obstructive pulmonary disease; WBC, white blood cell.

on ≥50% of days (94.8% vs 68.1%), have a measurement of LVEF (88.6% vs 76.7%, $P < 0.001$), and be referred to the HF clinic (48.5% vs 6.3%, $P < 0.001$). These rates did not significantly vary over the study period.

Clinical outcomes

Clinical outcomes in patients managed with vs without the HFOS in the overall cohort, the propensity-score matched

Table 2. Population characteristics in matched cohort

Characteristic	Order set (n = 724)	No order set (n = 724)	Standardized difference
Age (y)	74.6 ± 13.5	74.6 ± 13.6	−0.001
Male	391 (54.0)	387 (53.5)	−0.011
Cardiologist attending/consulting	562 (77.6)	555 (76.7)	−0.023
Past medical history			
Coronary artery disease	143 (19.8)	134 (18.5)	−0.032
Atrial fibrillation	248 (34.3)	252 (34.8)	0.012
Hypertension	366 (50.6)	375 (51.8)	0.025
Diabetes mellitus	248 (34.3)	234 (32.3)	−0.041
Peripheral vascular disease	10 (1.4)	7 (1)	−0.038
Cerebrovascular disease	10 (1.4)	12 (1.7)	0.023
Chronic kidney disease	114 (15.8)	114 (15.8)	0.000
COPD	102 (14.1)	102 (14.1)	0.000
Liver disease	79 (10.9)	79 (10.9)	0.000
Malignancy	29 (4)	26 (3.6)	−0.022
Dementia	25 (3.5)	23 (3.2)	−0.015
Charlson Comorbidity Index	4.7 ± 1.6	4.7 ± 1.6	−0.010
Systolic BP (mm Hg)	126.7 ± 21	126.3 ± 20.8	−0.019
Heart rate (bpm)	82 ± 19	83 ± 19	0.025
Creatinine (µmol/L)	126 ± 83	127 ± 116	0.009
Sodium (mmol/L)	137 ± 5	137 ± 4	−0.033
Hemoglobin (g/L)	123.2 ± 20.7	122.7 ± 21.5	−0.021
WBC (×10 ⁹ /L)	8.8 ± 3.6	8.7 ± 3.5	−0.020
Admission medications			
Beta-blocker	563 (77.8)	562 (77.6)	−0.003
ACE inhibitor/ARB	573 (79.1)	576 (79.6)	0.010

Values are n (%) or mean ± standard deviation. Daily weights expressed as a percentage of available days in the hospital, including day of discharge. ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker; BP, blood pressure; bpm, beats per minute; COPD, chronic obstructive pulmonary disease; WBC, white blood cell.

Figure 1. Summary of inpatient management in overall and propensity-score matched cohorts. In the overall cohort, there were treatment differences between patients managed with vs without the order set. These differences persisted in the propensity-score matched cohort, with the exception of discharge medication prescriptions. EF, ejection fraction; HF, heart failure; ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker.

cohort, and the limited propensity-score matched cohort are shown in Table 3. In total, 734 (8.2%) patients died in the hospital, and an additional 200 (2.2%) died within 30 days of discharge. Additionally, 812 (8.1%) patients were readmitted for HF within 30 days of discharge.

Associations between use of the HFOS and clinical outcomes are shown in Figure 2. In the overall cohort, mean hospital LOS was lower in patients managed with the HFOS (13.6 vs 19.1 days, $P < 0.001$ and median 8.4 vs 10.0 days, $P = 0.001$). Additionally, all-cause mortality within 30 days of discharge (including in-hospital deaths) was lower in patients managed with vs without the HFOS (4.5% vs 10.9%, $P < 0.001$).

The differences in hospital LOS (mean stay: 13.6 vs 16.3 days, $P = 0.016$; median: 8.6 vs 9.4 days, $P = 0.016$) and all-cause mortality (4.4% vs 7.2%, $P = 0.032$) were also seen in the propensity-score matched cohort. Similar results were seen in the limited propensity-score matched cohort (excluding patients with LOS > 30 days). There were no differences in 30-day repeat hospitalization (10.2% vs 10.8%, $P = 0.77$). There was also no difference in urgent readmissions for HF (defined as readmission through the emergency department)

between the propensity-score matched patients managed with vs without the HFOS (6.8% vs 6.9%, $P = 0.54$).

Discussion

In this study, the use of a comprehensive, standardized electronic HFOS was associated with a reduction in mean and median LOS as well as 30-day mortality in patients admitted with HF. In addition, a nearly significant, strong trend toward lower 30-day composite repeat hospitalization for HF and mortality was observed. The use of an HFOS was also associated with an increased likelihood of assessment of LVEF, use of daily weights, and referral to a multidisciplinary HF clinic. Use of evidence-based medications (ACE/angiotensin receptor blocker /beta-blockers) was lower in the overall cohorts; however, it was extremely high and not different between groups in the propensity-score matched analysis. To our knowledge, these data represent the first evidence of HF outcome improvements in a Canadian hospital setting. Importantly, shorter hospital LOS and reduced early mortality rates were not derived at the expense of repeat hospitalization for HF, which has a lower incidence in Canada than in other

Table 3. Clinical outcomes for patients managed with vs without the HF order set

Overall	Order set used (n = 731)	No order set (n = 8238)	P
Hospital LOS (d)	13.6 ± 18.0	19.1 ± 32.6	< 0.001
Hospital LOS (d), median	8.4	10.0	< 0.001
30-day readmissions for HF*	74 (10.6)	693 (9.5)	0.312
30-day all-cause mortality	33 (4.5)	901 (10.9)	< 0.001
30-day readmission for HF or all-cause mortality	107 (14.6)	1594 (19.4)	0.002
Propensity-score matched	Order set used (n = 724)	No order set (n = 724)	
Hospital LOS (d)	13.6 ± 18.0	16.3 ± 22.9	0.016
Hospital LOS (d), median	8.6	9.4	0.016
30-day readmissions for HF*	74 (10.2)	78 (10.8)	0.797
30-day all-cause mortality	32 (4.4)	52 (7.2)	0.032
30-day readmission for HF or all-cause mortality	105 (14.5)	128 (17.7)	0.115
Limited propensity-score matched, excluding LOS > 30 days	Order set used (n = 657)	No order set (n = 657)	
Hospital LOS (d)	9.5 ± 6.2	10.3 ± 6.7	0.020
30-day readmission for HF*	67 (10.2)	62 (9.4)	0.711
30-day all-cause mortality	32 (4.9)	95 (7.2)	0.001
30-day readmission for HF or all-cause mortality	98 (14.9)	122 (18.6)	0.089

Values are n (%) or mean ± standard deviation, unless otherwise indicated. All-cause mortality includes both in-hospital and postdischarge mortality.

HF, heart failure; LOS, length of stay.

* Calculated using survivors at hospital discharge.

jurisdictions⁴ and may lead to actual reduction of inpatient treatment costs for HF. The current results support ongoing study of the expansion of this approach to a wider patient population.

Comparison to literature

Use of multimodal interventions to reduce repeat hospitalization is not new.²⁰ Data from nonrandomized studies

Association Between Heart Failure Order Set Use and Clinical Outcomes

Figure 2. Association between heart failure order set use and clinical outcomes. In the limited propensity-score matched cohort, patients with a > 30-day length of stay were excluded. CI, confidence interval.

involving clinical pathway and/or order set have suggested improved outcomes for a variety of populations, including hospitalized HF patients.^{6–8,20–22} Ballard et al. showed that the use of a paper-based HFOS decreased in-hospital, but not 30-day, mortality in a propensity-score matched analysis.¹² Implementation of a CPOES within EMRs has been associated with fewer preventable adverse events due to medication errors and improved physician adherence to disease-specific process measures.^{6,23} There is evidence that CPOES use may also improve patient outcomes.^{12,24,25} We expand on the findings of Krive et al.¹³, by demonstrating improvement in clinical outcomes with use of an electronic HFOS after correcting for factors leading to utilization of the HFOS. Unfortunately, outcome data from randomized clinical trials of HFOS implementation and from the Canadian health care settings are lacking.²⁶

More specifically, studies of various sizes, ranging from 48 to 2875 identified cases, show that use of a CPOES is associated with consistent reductions in hospital LOS and short-term mortality, but not with repeat hospitalization.^{6,8,12,13} Key performance metrics for HF, such as ACE/angiotensin receptor blocker or beta-blocker therapy, in general were not statistically improved when correction for baseline characteristics, including treating physician and cardiology involvement, was performed. In contrast, nonmedical interventions, such as documentation of LVEF and measurement of daily weights, were consistently improved in the setting of CPOES usage.

Although we identified a significant reduction in 30-day mortality with use of the HFOS, we did not identify a reduction in 30-day readmission for HF. Patients managed with or without HFOS had shorter hospital LOS, and potentially had more residual congestion as a result.^{27,28} Sud et al. and others previously demonstrated that short LOS was an independent risk factor for readmission.²⁸ We also note that the lower mean LOS, coupled with lower mortality and similar 30-day readmission rates, would also translate into a greater number of days alive and out of hospital over the study period. Additionally, the lower 30-day mortality rate left a larger proportion of patients at risk for readmission (survivor bias). It is reassuring to note that in our study, lower LOS was observed, but not at the expense of increased repeat hospitalization and/or mortality, resulting in a higher number of days alive and out of the hospital, an increasingly used postdischarge outcome.²⁹ Lastly, this may be a result of the relatively small sample size and event rate (152 hospitalizations) in the propensity-score matched groups.

Regardless, the results of the present study are quite consistent with existing data on the impact of using an HFOS, aside from a lower usage rate (8.2% vs rates approaching 80%).⁶ This rate may have occurred due to an initial strategy of limited introduction of this CPOES to selected hospital wards, with little additional resources for dissemination coupled with inability to mandate usage. It is difficult to speculate on the potential impact of full implementation. Given that processes included in the CPOES are widely accepted discharge interventions, heterogeneity in usage rates

of discharge tools is well described, difficult to solve, and requires further study.^{30,31}

Strengths and limitations

This study considers an order set within a fully integrated CPOES, which permitted highly accurate data extraction, complete follow-up, and linkage to external databases. We included many consecutive cases (8969) over a prolonged period of time and were able to propensity-score match 724 CPOES cases for 25 variables, including specialist involvement in care.

Although all inpatient records from a single metropolitan Canadian city were included, limitations in data availability were nevertheless present. These included inability to determine actual LVEF, and listing of drug intolerances or reasons for medication use/non-use or earlier patient intolerance, a known limitation of electronic order sets.³ These and other variables either were not available (natriuretic peptides were available for <10% of the cohort) or were documented on the supplementary, paper-based charts, which were not formally audited in total. Consequently, variables known to affect outcomes, such as LVEF and serum B-type natriuretic peptide values, were not included. This study is nonrandomized and observational, with all the attendant potential bias this entails. Although many important clinical variables were well balanced in the matched groups, it is highly likely that several unmeasured confounders were present.

The lack of randomization allows for only a hypothesis-generating conclusion. Further, we cannot attribute any difference in outcomes to any specific mechanism of benefit, although we did observe increased use of nonpharmacologic, evidence-based therapies advocated within the HFOS, including documentation of LVEF, daily weight, and referral of high-risk patients to specialty HF clinics. We did not note any change in rate of daily weight or LVEF measurement over time in the HFOS group over the study period, which may have reflected a steady state of behavior. We did not more closely examine treatment behaviours, such as use of diuretic or other ancillary therapies. In addition, changes in clinical practice, such as introduction of angiotensin-neprilysin receptor inhibitors for HF with low LVEF are likely to have occurred following the study period. We were therefore, regrettably, not able to evaluate the HFOS as a tool to affect uptake of new treatments, which may have provided further insights as to the overall effectiveness of these treatments, especially given the potential for early reduction in hospitalization. We did not prospectively collect costing data, which would have informed a potential cost–benefit analysis.

In addition, the CPOES introduction was targeted primarily to locations where a high concentration of patients with HF would be found, and no formal effort was made to maintain or improve use over time, which likely led to the low usage rate, possibly among those with interest in HF. Thus, our findings may not be widely applicable to the generalist provider segment. Reasons for non-use of the order set were not recorded, and so we do not know if non-use was due to lack of awareness of the HFOS, patient factors, or other physician factors.

Conclusions

Use of a standardized, electronic HFOS for care of patients admitted to the hospital with HF was associated with shorter LOS and lower rates of death at 30 days. These results raise the possibility of savings of inpatient HF treatment costs and support the further expansion and rigorous studies designed to determine which components of the HFOS are most important in reducing adverse outcomes for patients admitted to the hospital with HF, and how they may be applied more broadly in the Canadian health care system. Additionally, given the potential clinical benefits of this intervention, barriers to widespread utilization should be identified and addressed.

Funding Sources

The authors have no funding sources to declare.

Disclosures

The authors have no conflicts of interest to disclose.

References

- Blais C, Dai S, Waters C, et al. Assessing the burden of hospitalized and community-care heart failure in Canada. *Can J Cardiol* 2014;30:352-8.
- Hayes SM, Peloquin S, Howlett JG, et al. A qualitative study of the current state of heart failure community care in Canada: what can we learn for the future? *BMC Health Serv Res* 2015;15:290.
- Howlett JG, Johnstone DE, Sketris I, et al. Identifying opportunities to address the congestive heart failure burden: the Improving Cardiovascular Outcomes in Nova Scotia (ICONS) study. *Can J Cardiol* 2003;19:439-44.
- Kaul P, Reed SD, Hernandez AF, et al. Differences in treatment, outcomes, and quality of life among patients with heart failure in Canada and the United States. *JACC Heart Failure* 2013;1:523-30.
- Maddocks H, Marshall JN, Stewart M, et al. Quality of congestive heart failure care: assessing measurement of care using electronic medical records. *Can Fam Physician* 2010;56:e432-7.
- Butler J, Speroff T, Arbogast PG, et al. Improved compliance with quality measures at hospital discharge with a computerized physician order entry system. *Am Heart J* 2006;151:643-53.
- Fonarow GC, Abraham WT, Albert NM, et al. Influence of a performance-improvement initiative on quality of care for patients hospitalized with heart failure: results of the Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients With Heart Failure (OPTIMIZE-HF). *Arch Intern Med* 2007;167:1493-502.
- Garin N, Carballo S, Gerstel E, et al. Inclusion into a heart failure critical pathway reduces the risk of death or readmission after hospital discharge. *Eur J Intern Med* 2012;23:760-4.
- Jaspers MW, Smeulders M, Vermeulen H, Peute LW. Effects of clinical decision-support systems on practitioner performance and patient outcomes: a synthesis of high-quality systematic review findings. *J Am Med Inform Assoc* 2011;18:327-34.
- Bradley EH, Curry L, Horwitz LI, et al. Hospital strategies associated with 30-day readmission rates for patients with heart failure. *Circ Cardiovasc Qual Outcomes* 2013;6:444-50.
- Grol R, Grimshaw J. From best evidence to best practice: effective implementation of change in patients' care. *Lancet* 2003;362:1225-30.
- Ballard DJ, Ogola G, Fleming NS, et al. Impact of a standardized heart failure order set on mortality, readmission, and quality and costs of care. *Int J Qual Health Care* 2010;22:437-44.
- Krive J, Shoolin JS, Zink SD. Effectiveness of evidence-based congestive heart failure (CHF) CPOE order sets measured by health outcomes. *AMIA Annu Symp Proc* 2014;2014:815-24.
- Arnold JM, Liu P, Demers C, et al. Canadian Cardiovascular Society consensus conference recommendations on heart failure 2006: diagnosis and management. *Can J Cardiol* 2006;22:23-45.
- Malcom J, Arnold O, Howlett JG, et al. Canadian Cardiovascular Society Consensus Conference guidelines on heart failure—2008 update: best practices for the transition of care of heart failure patients, and the recognition, investigation and treatment of cardiomyopathies. *Can J Cardiol* 2008;24:21-40.
- World Health Organization (WHO). ICD-10 : International Statistical Classification of Diseases and Related Health Problems: tenth revision. 2nd ed. Geneva: WHO, 2004.
- Southern DA, Norris CM, Quan H, et al. An administrative data merging solution for dealing with missing data in a clinical registry: adaptation from ICD-9 to ICD-10. *BMC Med Res Methodol* 2008;8:1.
- Horsky J, Drucker EA, Ramelson HZ. Accuracy and completeness of clinical coding using ICD-10 for ambulatory visits. *AMIA Annu Symp Proc* 2018;2017:912-20.
- Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40:373-83.
- Meleskie J, Eby D. Adaptation and implementation of standardized order sets in a network of multi-hospital corporations in rural Ontario. *Healthc Q* 2009;12:78-83.
- Legrain S, Tubach F, Bonnet-Zamponi D, et al. A new multimodal geriatric discharge-planning intervention to prevent emergency visits and rehospitalizations of older adults: the optimization of medication in AGEd multicenter randomized controlled trial. *J Am Geriatr Soc* 2011;59:2017-28.
- Rivers EP, Coba V, Rudis M. Standardized order sets for the treatment of severe sepsis and septic shock. *Expert Rev Anti Infect Ther* 2009;7:1075-9.
- Nuckols TK, Smith-Spangler C, Morton SC, et al. The effectiveness of computerized order entry at reducing preventable adverse drug events and medication errors in hospital settings: a systematic review and meta-analysis. *Syst Rev* 2014;3:56.
- Ballesca MA, LaGuardia JC, Lee PC, et al. An electronic order set for acute myocardial infarction is associated with improved patient outcomes through better adherence to clinical practice guidelines. *J Hosp Med* 2014;9:155-61.
- Spaulding TJ, Raghu TS. Impact of CPOE usage on medication management process costs and quality outcomes. *Inquiry* 2013;50:229-47.
- Wells C, Loshak H. Standardized Hospital Order Sets in Acute Care: A Review of Clinical Evidence, Cost-Effectiveness, and Guidelines. Ottawa (ON): Canadian Agency for Drugs and Technologies in Health, 2019.
- Metra M, Davison B, Bettari L, et al. Is worsening renal function an ominous prognostic sign in patients with acute heart failure? The role of

- congestion and its interaction with renal function. *Circ Heart Fail* 2012;5:54-62.
28. Sud M, Yu B, Wijeyesundera HC, et al. Associations between short or long length of stay and 30-day readmission and mortality in hospitalized patients with heart failure. *JACC Heart Fail* 2017;5:578-88.
 29. Fanaroff AC, Cyr D, Neely ML, et al. Days alive and out of hospital: exploring a patient-centered, pragmatic outcome in a clinical trial of patients with acute coronary syndromes. *Circ Cardiovasc Qual Outcomes* 2018;11:e004755.
 30. Wiggins BS, Rodgers JE, DiDomenico RJ, Cook AM, Page RL 2nd. Discharge counseling for patients with heart failure or myocardial infarction: a best practices model developed by members of the American College of Clinical Pharmacy's Cardiology Practice and Research Network based on the Hospital to Home (H2H) Initiative. *Pharmacotherapy* 2013;33:558-80.
 31. Wright A, Feblowitz JC, Pang JE, et al. Use of order sets in inpatient computerized provider order entry systems: a comparative analysis of usage patterns at seven sites. *Int J Med Inform* 2012;81:733-45.

Supplementary Material

To access the supplementary material accompanying this article, visit *CJC Open* at <https://www.cjcopen.ca/> and at <https://doi.org/10.1016/j.cjco.2020.06.009>.