Results: A total of 285 unique patients were identified. Of these, 135 patients (47.3%) were managed by an HF service, and 82 (28.7%) died. A total of 150 patients (52.6%) were co-propensity score adjusted association between HF consultation and in-hospital mortality.

Methods: We identified all adult patients admitted to the cardiac intensive care unit (2014-2015) at the University Health Network with a diagnosis of acute decompensated HF ± cardiogenic shock (CS). Clinical characteristics and course were recorded. We calculated a propensity score-adjusted association between HF consultation and in-hospital mortality.

Results: A total of 285 unique patients were identified in our cohort. Of these, 82 (28.7%) died. A total of 150 patients (52.6%) were co-managed by an HF service, and 135 patients (47.3%) were not.

Heart failure (HF) affects more than 1 million Canadians each year, with approximately 600,000 newly diagnosed cases annually. Currently, 1 in 5 Canadians will have HF during their lifetime. It is estimated that it costs the Canadian healthcare system more than $2.8 billion dollars annually, with the highest economic burden seen in the last 6 months of life. Economic analysis shows a marked increase in hospital costs during the final 2 years of life, especially in the last 6 months with longer days spent in hospital. HF admissions account for the second highest number of days in hospital when compared with other chronic diseases and is projected to account for up to 80,000 admissions in Canada by 2025.

Given the large number of patients admitted to the hospital with HF, they are often admitted to Internal Medicine or Cardiology services. Multiple studies have shown the benefit of close cardiology follow-up in improving the management of these patients. In one study, cardiology service discharge summaries were more likely to have details, which include reassessment of left ventricular ejection fraction (LVEF), inpatient study results (ie, laboratory work, imaging results), discharge weight and vital signs, and a discharge physical examination. Furthermore, multiple studies have shown that patients followed in a HF clinic at the time of hospital discharge had higher use of guideline-directed medical therapy (GDMT) and a reduction in hospitalizations and mortality. Despite these benefits, a Canadian population-based study found that a cardiologist saw only 54.9% of patients with an index HF diagnosis in the subsequent 2.5 to 3.5 years.

Despite the evidence that close cardiology follow-up improves clinical outcomes, there is currently no data examining the role of a dedicated HF specialist consultation alongside the cardiac intensive care unit (CICU) team. Most recently, there is new evidence that suggests a "team-based approach"
Patients who were managed by an HF team were younger (52.5 vs 68.0 years, \( P < 0.0001 \)), were more likely to be admitted with CS (61.3 vs 41.5\%, \( P < 0.0009 \)), and had higher rates of vasoactive medications during their admission (69.3\% vs 52.6\%, \( P < 0.005 \)). At discharge, there were higher rates of discharge to a HF clinic (52.0\% vs 27.5\%, \( P < 0.0001 \)) and prescription of guideline-directed medical therapy. In-hospital mortality was lower in those co-managed by a HF team (16.7\% vs 42.2\%, \( P < 0.0001 \)). HF consultation reduced the odds of readmission by 76\% (odds ratio, 0.24; 95\% confidence interval, 0.13-0.47).

Conclusions: Patients managed by a HF team were more likely to be in CS at admission, to survive to discharge from hospital, and to be initiated on guideline-directed medical therapy with HF follow-up.

Patients with cardiogenic shock (CS) involving a shock team leads to increased 30-day survival rates.\(^{10,11} \) In the present study, we aimed to compare patients admitted to the CICU with acute decompensated heart failure (ADHF) with or without CS who received a consultation with a dedicated HF team with patients who did not.

Methods

Study population

We retrospectively identified 329 consecutive adult patients from our CICU registry with a diagnosis of HF (with or without CS) who were admitted to the Peter Munk Cardiac Centre CICU, University Health Network (January 1, 2014, to December 31, 2015). The majority of the CICU attendings have expertise in interventional cardiology (n = 6), with 1 general cardiologist and 1 HF specialist. The HF specialist, once involved, would co-manage the patient with the CICU team (rounding daily) with continued involvement once discharged from the CICU. The University Health Network research ethics board review committee approved this study.

Patients in our population were admitted from an emergency department or our inpatient ward (medicine or cardiology services) or transferred from other hospitals for specialized care. The diagnosis of HF was made by the treating physician(s) and required documentation of their clinical presentation and physical examination. Findings included the presence of at least 1 symptom (dyspnea, orthopnea, abdominal bloating, or edema) and 1 sign (rales, peripheral edema, ascites, or pulmonary congestion on chest x-ray).\(^{12} \) The diagnosis of CS was made if the patient had a systolic blood pressure of < 90 mmHg for ≥ 30 minutes or requirement for vasopressors or inotropes, evidence of end-organ hypoperfusion (urine output < 30 mL/h for 6 hours or lactate > 2), or hemodynamic criteria (from right heart catheterization, echocardiography, and clinical criteria of elevated jugular venous pressure, presence of S3 or rales).\(^{13} \)

Patients were included in this study on the basis of HF diagnosis, which included preserved (defined as an LVEF ≥ 50\%) or reduced LVEF (defined as an LVEF < 50\%).\(^{14} \) Patients who received orthotopic heart transplant (OHT) or mechanical circulatory support (MCS) (ie, left ventricular assist device or extracorporeal membrane oxygenation), and those with established mixed shock were excluded (ie, confirmed septic shock). The former group was excluded because these modalities mandated a mandatory HF consultation. If a patient was admitted to the CICU on more than 1 occasion during a single admission to hospital, only the index admission was included in the analysis.

Clinical information including comorbid illnesses, admission medications, vital, laboratory values, interventions received while in the CICU, discharge medications, and CICU and hospital length of stay (LOS) were extracted from the patient’s electronic medical record. The presence of a consultation from a dedicated HF service and follow-up in a multidisciplinary clinic were recorded. Readmission rates (up to 90 days) were also tabulated.

Statistical analysis

Normal and nonparametric distributed continuous variables were presented as mean ± standard deviation. Categorical variables are shown as percentages. Student t test and Wilcoxon rank-sum test were used to compare normal and nonparametric continuous variables, and Fisher exact tests were used for categorical variables.

We calculated a propensity score for each patient by matching according to age, LVEF, hypertension, dyslipidemia, diabetes mellitus, cerebrovascular accident, peripheral vascular disease, heart rate, type of cardiomyopathy (ischemic vs nonischemic), admission for CS, and inotropic use and pulmonary artery catheterization at the time of admission. We
| Characteristic | All patients (n = 285) | With HF consult (n = 150) | Without HF consult (n = 135) | P value |
|---------------|------------------------|---------------------------|-----------------------------|---------|
| Age (y, mean ± SD) | 59.9 ± 18.3 | 52.5 ± 16.3 | 68.0 ± 17.0 | 0.0001 |
| Men, n (%) | 196 (68.8) | 102 (68) | 94 (70.0) | 0.8 |
| LVEF at time of admission (mean ± SD) | 31.3 ± 14.4 | 27.0 ± 12.4 | 35.7 ± 15.4 | 0.0001 |
| LVEF ≥ 50% at time of admission (n, %) | 55 (19.3) | 15 (10) | 40 (30) | 0.0001 |
| Comorbidities (n, %) | | | | |
| Hypertension | 127 (44.6) | 57 (38) | 70 (51.9) | 0.023 |
| Dyslipidemia | 97 (34) | 40 (26.7) | 57 (42.2) | 0.006 |
| Diabetes mellitus | 90 (31.6) | 40 (26.7) | 50 (37.0) | 0.08 |
| Previous myocardial infarction | 86 (30.2) | 35 (23.3) | 51 (37.8) | 0.001 |
| Previous PCI | 54 (18.8) | 24 (16) | 30 (22.2) | 0.23 |
| Previous CARG | 43 (15.1) | 18 (12) | 25 (18.5) | 0.14 |
| Chronic kidney disease | 78 (27.3) | 36 (24) | 42 (31.1) | 0.19 |
| Cerebrovascular accident | 25 (8.7) | 6 (4) | 19 (14.1) | 0.003 |
| Peripheral vascular disease | 24 (8.4) | 7 (4.7) | 17 (12.6) | 0.02 |
| Previous history of CHF | 169 (59.3) | 90 (60) | 79 (58.5) | 0.81 |
| Previous history of VF/VT | 26 (9.1) | 10 (6.7) | 16 (12) | 0.01 |
| Previous history of atrial fibrillation | 120 (42) | 60 (39.3) | 60 (44.4) | 0.08 |
| Presence of permanent pacemaker | 20 (6.9) | 10 (6.7) | 10 (7.5) | 0.70 |
| Presence of ICD | 54 (19.0) | 27 (18) | 27 (20.2) | 0.45 |
| Presence of CRT-D | 17 (6) | 8 (5.3) | 9 (6.7) | 0.65 |
| Chronic obstructive pulmonary disease | 25 (8.7) | 13 (8.7) | 12 (9.0) | 0.56 |
| Current smoker | 25 (8.7) | 13 (8.7) | 12 (9.0) | 0.68 |
| Previous smoker | 52 (18.2) | 28 (18.7) | 24 (17.8) | 0.88 |
| Previous history of mental health | 26 (9.1) | 13 (8.7) | 13 (9.7) | 0.01 |
| ACHD | 11 (3.8) | 5 (3.3) | 6 (4.4) | 0.76 |
| Admission medications | | | | |
| ASA | 96 (33.7) | 46 (30.7) | 50 (37.0) | 0.26 |
| Thienopyridine | 41 (14.4) | 12 (8) | 29 (21.5) | 0.001 |
| Beta-blocker | 176 (61.7) | 89 (59.3) | 87 (64.4) | 0.39 |
| ACEi/ARB | 111 (38.9) | 62 (41.3) | 49 (36.3) | 0.40 |
| ARNI | 1 (0.4) | 1 (0.7) | 0 (0) | 1.0 |
| Aldosterone antagonist | 85 (29.8) | 55 (36.7) | 30 (22.2) | 0.009 |
| CCB | 22 (7.7) | 9 (6) | 13 (9.6) | 0.30 |
| Loop diuretic | 186 (65) | 89 (59.3) | 97 (71.8) | 0.03 |
| Hydralazine | 25 (8.7) | 12 (8) | 13 (9.6) | 0.68 |
| Nitrates | 21 (7.4) | 11 (7.3) | 10 (7.4) | 1.0 |
| Digoxin | 67 (23.5) | 47 (31.3) | 20 (14.8) | 0.001 |
| Statin | 133 (46.6) | 65 (43.3) | 68 (50.3) | 0.24 |
| Insulin | 34 (11.8) | 15 (10) | 19 (14.1) | 0.36 |
| Anticoagulation | 73 (25.6) | 43 (28.7) | 30 (22.2) | 0.22 |
| Admission vitals (mean ± SD) | | | | |
| Heart rate | 88.7 ± 23.1 | 91.7 ± 23.4 | 85.4 ± 22.6 | 0.02 |
| Respiratory rate | 19.9 ± 4.4 | 19.8 ± 4.6 | 20 ± 4.2 | 0.70 |
| Mean arterial pressure | 74.8 ± 16.4 | 76.2 ± 16.4 | 73.4 ± 16.4 | 0.15 |
| Systolic blood pressure | 105.3 ± 20.3 | 105.2 ± 17.3 | 105.4 ± 23.3 | 0.93 |
| Diastolic blood pressure | 61.1 ± 12.5 | 63.1 ± 13.6 | 59 ± 10.8 | 0.005 |
| Admission laboratory values (mean ± SD) | | | | |
| Hemoglobin (g/L) | 117.3 ± 25.8 | 122.0 ± 27.9 | 112.8 ± 22.9 | 0.003 |
| Sodium (mmol/L) | 133.5 ± 16.4 | 132.7 ± 18.9 | 134.2 ± 13.0 | 0.46 |
| Creatinine (μmol/L) | 180.6 ± 127.4 | 172.5 ± 129.5 | 190.4 ± 124.9 | 0.29 |
| Serum lactate (mmol/L) | 3.3 ± 3.2 | 3.2 ± 2.9 | 3.5 ± 3.5 | 0.43 |
| Admission diagnosis (n, %) | | | | |
| Etiology of CHF | | | | |
| Ischemic | 98 (34.4) | 42 (28) | 56 (41.5) | 0.02 |
| Nonischemic | 187 (65.6) | 108 (72) | 79 (58.5) | 0.02 |
| CICU admission for CS | 148 (51.9) | 92 (61.3) | 56 (41.5) | 0.0009 |
| Admission with concurrent: | | | | |
| ACS | 4 (1.4) | 0 (0) | 4 (3.0) | 0.05 |
| Arrhythmia | 4 (1.4) | 3 (2) | 1 (0.7) | 0.62 |
| Post-cardiac arrest | 4 (1.4) | 3 (2) | 1 (0.7) | 0.62 |
| Interventions at time of CICU admission (n, %) | | | | |
| Inotrope/vasopressor use | 175 (61.4) | 104 (69.3) | 71 (52.6) | 0.005 |
| Mechanical ventilation | 57 (20) | 32 (21.3) | 25 (18.5) | 0.66 |
| BIPAP | 20 (7.1) | 6 (4) | 14 (10.4) | 0.04 |
| IABP | 10 (3.5) | 6 (4.2) | 6 (4.4) | 0.52 |
| Impella (Abiomed, Danvers, MA) | 7 (2.5) | 3 (2) | 4 (3.0) | 0.71 |
| Use of pulmonary artery catheter | 99 (34.7) | 60 (40) | 39 (28.9) | 0.06 |
| IHD | 26 (9.1) | 16 (10.7) | 15 (11.1) | 1.00 |

Continued
conducted our propensity score matching by using the nearest neighbour matching method.

All statistical tests were 2 sided, and a P value of < 0.05 was set to be statistically significant. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Inc., Cary, NC) and STATA version 15.1.

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**Results**

**Patient characteristics**

During the study period, 2378 patients were admitted to the CICU at the Peter Munk Cardiac Centre, with 329 unique patients admitted with a diagnosis of HF with or without CS. Of these patients, 44 (13.4%) received OHT or MCS during their hospitalization and were excluded. Of the remaining 285 patients, the mean age was 59.9 years, 68.8% (n = 196) were male, and 19.3% (n = 55) had heart failure preserved ejection fraction (HFrEF). Eighty-two patients (28.8%) died during their hospital stay. A total of 150 patients (52.6%) had an HF specialist consultation during their hospitalization and were excluded. Of the unique patients admitted with a diagnosis of HF with or without CS to the CICU who were co-managed with a dedicated HF consultation service were younger, more likely to have a nonischemic cause of HF, and more likely to have HFrEF and comorbid illness. In this retrospective study, we found that patients admitted with HF with or without CS to the CICU who were co-managed with a dedicated HF consultation service were more likely to survive to discharge despite increased acuity and illness severity at time of CICU admission (ie, higher rates of presentation with CS and vasopressor use). In addition, our study revealed that those seen by an HF consultant were also more likely to leave hospital on GDMT if they had heart failure reduced ejection fraction (HFrEF).

Upon looking at these 2 groups, there are clear differences in baseline characteristics. Those seen by an HF team were younger, more likely to have a nonischemic cause of HF, and more likely to have HFrEF and a previous diagnosis of HFrEF. In addition, they were also more likely to be in CS on admission to the CICU, requiring more aggressive medical therapy.

Those patients not co-managed by an HF team were older and more likely to have HFpEF and comorbid illness. In this clinical scenario, an HF consultation may not have been sought because older patients or those with HFpEF were presumed ineligible for advanced therapies. It is also possible that there is a perception that HF expertise is not necessary because HFpEF does not benefit from conventional HF therapy. However, this subgroup is difficult to treat, and because the prognosis is similar to that of patients with HFrEF,15-17 an argument could be made for specialist consultation. Because there are currently no studies looking at the role of a specialized HF consultant in the management of the HFpEF population, further research is needed to assess whether HF consultation provides an incremental benefit in the inpatient setting. Although there are significant differences between both groups (ie, age, severity of illness, blood work (hemoglobin, sodium, creatinine, and lactate) was also not significant different.

At the time of discharge, patients who received an HF consultation during their hospitalization were more likely to be seen in follow-up in the HF clinic (52.0% vs 27.5%, P < 0.0001) and to be on GDMT (Table 2). These findings remain consistent even after excluding patients with HFpEF (Table 3). In-hospital mortality was lower in those co-managed by an HF consultation service (16.7% vs 42.2%, < 0.0001). After propensity score matching, HF consultation was associated with lower odds of in-hospital mortality (odds ratio, 0.24; 95% confidence interval, 0.13-0.47). Hospital and CICU LOS were not statistically significant. There was no significant difference between readmission rates (19.3% vs 14.1%, P = 0.27).

**Discussion**

In this retrospective study, we found that patients admitted with HF with or without CS to the CICU who were co-managed with a dedicated HF consultation service were more likely to survive to discharge despite increased acuity and illness severity at time of CICU admission (ie, higher rates of presentation with CS and vasopressor use). In addition, our study revealed that those seen by an HF consultant were also more likely to leave hospital on GDMT if they had heart failure reduced ejection fraction (HFrEF).

**Table 1. Continued.**

| Characteristic          | All patients (n = 285) | With HF consult (n = 150) | Without HF consult (n = 135) | P value |
|-------------------------|------------------------|--------------------------|-----------------------------|---------|
| In-hospital mortality   | 82 (28.7)              | 25 (16.7)                | 57 (42.2)                   | 0.0001  |
| LOS (d, mean ± SD)      | 6.5 ± 8.13             | 6.4 ± 6.1                | 6.8 ± 10.0                  | 0.68    |
| CICU length of stay     | 23.9 ± 27.6            | 20.8 ± 19.5              | 25.4 ± 34.4                 | 0.16    |

ACEi, angiotensin-converting enzyme inhibitor; ACS, acute coronary syndrome; ARB, angiotensin II receptor blocker; ARNI, angiotensin receptor-neprilysin inhibitor; ASA, acetylsalicylic acid; BIPAP, bilevel positive airway pressure; CABG, coronary artery bypass grafting; CHF, congestive heart failure; CICU, cardiac intensive care unit; CRT-D, cardiac resynchronization therapy-defibrillator; CS, cardiogenic shock; HF, heart failure; IABP, intra-aortic balloon pump; ICD, implantable cardioverter-defibrillator; IHD, intermittent hemodialysis; LOS, length of stay; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention; VF, ventricular fibrillation; VT, ventricular tachycardia.
comorbidities), these differences may be a result of existing referral patterns within our institution. These results could be explained by the fact that the Peter Munk Cardiac Centre is a quaternary care center that offers OHT and MCS that necessitates earlier involvement by an HF team to ensure that the window for accessibility to these resources is timely. Critically ill young patients likely prompt earlier HF referral.

In-hospital mortality was lower in those co-managed by a dedicated HF team, despite higher rates of CS at time of admission. Because ADHF with organ impairment is clinically challenging to manage, expertise and specialized training in advanced HF and cardiac critical care may allow earlier identification of illness severity, more aggressive decongestive therapies, and more rapid initiation and withdrawal of inotropes/vasopressors, which may potentially explain the lower rates of in-hospital mortality. A larger change in weight loss during hospitalization was seen in the group followed by an HF team (7.7 ± 8.9 kg vs 4.8 ± 4.8 kg, P = 0.004) compared with those who were not. Although weight loss could be also due to loss of muscle mass in light of acute illness, the CICU and hospital LOS were similar between both groups.

This study also demonstrates that patients with HFrEF seen by an HF consultant were more likely to be discharged on GDMT (Tables 2 and 3). Although the introduction of beta-blockers and diuretics were not statistically different between both groups, the use of vasodilators, aldosterone antagonists, and digoxin were higher in patients co-managed by an HF team. Possible reasons for a lack of GDMT at the time of discharge include the lack of knowledge of timing of initiating these therapies or the avoidance of polypharmacy in the elderly population, it remains unclear why this discrepancy exists. Multiple guidelines, based on robust data, encourage early introduction of these therapies. However, further studies are needed to identify gaps in applying guidelines into clinical practice.

In addition, patients with HF consultation were more likely to be seen in follow-up at a multidisciplinary HF clinic (63.4% vs 27.5%, P < 0.0001). Access to timely follow-up in a multidisciplinary HF clinic has been shown to reduce hospital readmissions at 6 months and subsequent visits to the emergency department, as well as an improvement in quality of life.20,21 Although multiple studies have shown reduced mortality in patients discharged from hospital with ADHF with follow-up with a cardiologist compared with a noncardiologist (ie, family practice),6,7 there are no studies examining whether mortality rates differ among cardiac specialties (ie, HF specialist vs general cardiologist). Further investigations are needed to examine this particular clinical question.

As the incidence of HF in our population continues to increase, there will undoubtedly continue to be a varied group of front-line providers (with varying degrees of training) who manage this patient population in the inpatient and outpatient settings. Although there is significant evidence showing that management of these patients by cardiologists leads to a reduction in emergency department use and an improvement in quality of life, this is the first study that demonstrates the added benefit of subspecialized training in advanced HF and transplant cardiology in reducing in-hospital mortality and improving rates of initiation of GDMT while in the hospital. Most recently, the Accreditation Council for Graduate Medical Education has issued an American Board of Internal Medicine added qualification designation for advanced HF and transplant cardiology, with clear published training requirements that include the management of critically ill patients with CS, MCS, and OHT.22 With more than 80 training programs in North America (74 in the United States and 6 in Canada) currently, the growth of a critical mass of specialty-trained providers, alongside primary care providers

**Table 2. Medications at time of discharge for survivors dichotomized to those receiving HF consultation vs those without subspecialty consultation**

| Discharge medications | Patients with HF consultation (n = 125) | Patients without HF consultation (n = 78) | P value |
|------------------------|----------------------------------------|-----------------------------------------|--------|
| ACE/ARB or ARNI        | 69 (55.2)                              | 27 (34.6)                               | 0.01   |
| Beta-blocker           | 87 (69.6)                              | 45 (57.6)                               | 0.19   |
| Aldosterone antagonists| 78 (62.4)                              | 22 (28.2)                               | 0.0001 |
| ISDN/hydralazine       | 38 (30.4)                              | 12 (15.4)                               | 0.029  |
| Digoxin                | 61 (48.8)                              | 10 (12.8)                               | 0.0001 |
| Lasix                  | 83 (66.4)                              | 53 (67.9)                               | 0.66   |

ACE, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; ARNI, angiotensin receptor-neprilysin inhibitor; HF, heart failure; ISDN, isosorbide dinitrate.
and general interns, will be needed to tackle the growing HF epidemic. In addition, the delivery of care that is currently available mostly at specialty centers appears to be unsustainable over the next decade. New guidelines have suggested the role of a spoke-hub-and-node model, where patient complexity dictates where they are best managed. As patients fluidly move between functional states, it may not be simple to rely solely on functional status to stratify patients because accompanying comorbid illness and frailty add an extra layer of complexity in their management. System-wide planning to tackle the significant burden of HF will be needed to address this growing public health concern.

The present study highlights the need for HF consultation for patients admitted to the CICU setting. Despite the fact that the subset of patients co-managed by an HF specialist were more likely in CS necessitating vasopressor or inotrope therapy, we have shown that these patients are managed more aggressively with decongestive therapies leading to a larger net weight loss during their hospital stay. In addition, this subgroup was more likely to survive to discharge with higher rates of GDMT use and with follow-up in a multidisciplinary HF clinic. This study reiterates the need for specialist HF consultation as suggested by the National Institute for Health and Care Excellence.

Limitations
There are several limitations to address in this study. First, this study is from a single academic institution whose focus is on advanced HF therapies. This may make it difficult to generalize these findings to other hospital sites. In addition, because our hospital services many community sites, we were not able to capture readmission rates or deaths at other hospitals. Our dataset also does not focus on emergency department use within our institution or our community partners. Finally, our data set did not evaluate the degree of complexity or severity of comorbid illnesses that may have contributed to each patient’s hospital trajectory.

Conclusion
A dedicated HF consultation service is an integral component of managing the critically ill population of patients admitted to the hospital with a diagnosis of HF or CS. Although patients managed by an HF team were more likely to be in CS with higher rates of use of vasoactive agents, they had a lower rate of in-hospital mortality and were more likely to be discharged on GDMT with follow-up in an HF clinic compared with those managed exclusively by their primary team. As such, this study highlights the importance of involving a HF specialty consultation service for patients admitted to the CICU with HF to reduce mortality and to optimize medical therapy at time of discharge.

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