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Research paper

Outcomes of COVID-19 in heart failure, LVAD, and heart transplant patients in an advanced heart failure practice

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ABSTRACT

Background: Patients with heart failure face increased morbidity and mortality when infected with COVID-19. The objective of this study was to evaluate the outcomes of patients with Heart Failure (HF), Left Ventricular Assist Devices (LVADs), or Heart Transplants (HTx) diagnosed with COVID-19 within an advanced HF practice.
Methods: Out of 2635 patients followed, 96 patients were diagnosed with COVID-19 between March 2020 and January 2021. Median hospital length of stay (LOS), requirement for mechanical ventilation (MV), and mortality rate were evaluated.
Results: The distribution of COVID-19 among the 96 patients was: HF = 43 (45 %), LVAD = 16 (17 %) and HTx = 37 (38 %). Among 43 HF patients, 5 (12 %) died, 18 (42 %) required hospitalization with an LOS of 7 days, 5 (12 %) required ICU and 4 (9 %) required MV. Of the 16 LVAD patients, 2 (13 %) died, 8 (50 %) required hospitalization with an LOS of 11 days, 3 (19 %) required ICU and 3 (19 %) required MV. Among 37 HTx patients, 7 (19 %) died, 23 (62 %) required hospitalization with an LOS of 9 days, 6 (16 %) required ICU and 6 (16 %) required MV.
Conclusion: This report is among the first to describe the impact of COVID-19 on a diverse advanced HF practice. It highlights the risks associated with COVID-19 faced by the HF, LVAD and HTx patients. A 90-day mortality rate of 19 % with HTx patients acquiring COVID-19 is ominous as is a mortality rate of 12 % each for HF and LVAD patients. This clinical impact should serve as a reminder of unique challenges with these populations.

1. Introduction

Coronavirus Disease 2019 (COVID-19) is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). COVID-19 rapidly became a global pandemic after it was first identified in Wuhan, China and reported to World Health Organization (WHO) on December 31, 2019 [1]. Systemically, SARS-CoV-2 can affect multiple organs including heart, lung, kidney, liver, pancreas, intestine, skeletal muscle, central nervous system, adrenal, and thyroid glands [2]. More than 250 million cases and 5 million deaths globally were reported during the first two years of the pandemic [3].

Early studies indicated that myocardial injury is not uncommon among hospitalized patients with COVID-19 [4]. Risk factors for myocardial injury and increased mortality include older age, hypertension, diabetes, cardiovascular disease (CVD), chronic heart failure, chronic obstructive pulmonary disease (COPD), and cancer [4–6]. A meta-analysis of 16 studies with 307,596 patients (15 % with CVD) suggested that those with CVD who developed COVID-19 had >4-fold higher risk of mortality [7]. A systematic review and meta-analysis of 10,898 patients showed that those with preexisting cardiovascular disease were nearly eight times more likely to have fatal outcomes [8]. Heart failure (HF) patients appear to have an increased risk of morbidity and mortality [6,9]. Out of 692 COVID-19 patients from 13 different cardiology centers in Italy, patients with HF had twice the mortality of patients without HF [10]. Discontinuation of HF medications during hospitalization for COVID-19 significantly increased the risk of mortality [11].

LVAD and HTx patients who contract COVID-19 experience

Abbreviations: COVID-19, Coronavirus Disease-2019; ACC, American College of Cardiology; AHA, American Heart Association; HF, Heart Failure; HF-C/D, Stage C or D Heart Failure; LVAD, Left Ventricular Assist Device; HTx, Heart Transplantation.

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additional risk due to multiple concomitant comorbidities and immunosuppression. A study of 47 heart transplant patients with COVID-19 (out of 2676 heart transplant recipients) from 7 transplant centers in Northern Italy demonstrated a two-fold increase of case fatality rates when compared to hospitalized non-transplant patients [12]. Patients on chronic immunosuppression may have increased and prolonged COVID-19 viral loads resulting in heightened infectivity and poor prognosis [12]. A retrospective US study of 28 heart transplant patients with COVID-19 from a cohort of 803 heart transplant recipients showed a mortality rate of 25 % and hospitalization rate of 79 %. A higher incidence of comorbid conditions such as hypertension, diabetes, obesity, chronic kidney disease (CKD), and cardiac allograft vasculopathy, was observed in patients who died [13].

The objective of this retrospective review was to evaluate the outcomes of patients with ACC/AHA stage C or D heart failure (HF-C/D), Left Ventricular Assist Devices (LVAD), or Heart Transplantation (HTx) who were diagnosed with COVID-19.

2. Methods

The setting of this study is an advanced HF program associated with a 500-bed acute care facility in a moderate-size metropolitan area serving a multi-state surrounding region. The program offers a wide range of HF services from general cardiology to advanced therapies, including LVAD implantation, extracorporeal membrane oxygenation (ECMO), and the state's only heart transplantation center. A retrospective review of the medical records of all patients diagnosed with COVID-19 ($n = 96$) was conducted among the 2635 patients followed during the period from March 2020 to January 2021. This time period includes the onset of the pandemic until the availability of vaccines. The rate of hospitalization, hospital length of stay (LOS), need for intensive care unit (ICU) support, mechanical ventilation, requirement for oxygen at discharge and mortality were reviewed among all three groups of patients with HF-C/D, LVADs and HTx. The research protocol was approved by the Institutional Review Board. All data were extracted from electronic medical records and de-identified.

2.1. Statistical analysis

Statistical analysis was performed using the SPSS statistical package (IBM, version 26, New York). Results were presented as mean ± SD (median) or number (%). Differences between groups were analyzed using the independent *t*-test for continuous variables and Fisher's exact test for categorical variables. Mann-Whitney *U* test was used for variables that did not display a normal distribution. Ninety-day survival curves were generated using the Kaplan-Meier method and compared by the log-rank test. All statistical tests were two-sided, and differences were considered significant when $p \leq 0.05$.

3. Results

Out of 2635 patients followed (HF-C/D = 2234, LVAD = 167, HTx = 234), 96 patients (3.6 %) were diagnosed with COVID-19 infection between March 2020 to January 2021 [HF-C/D = 43 (45 %), LVAD = 16 (17 %), and HTx = 37 (38 %)]. Demographics and clinical characteristics of the three cohorts are described in Table 1. Among the 43 HF-C/D patients, 5 (12 %) died, 18 (42 %) required hospitalization with a median hospital LOS of 7 days, 5 (12 %) required ICU and 4 (9 %) required mechanical ventilation. Of the 16 LVAD patients, 2 (13 %) died, 8 (50 %) required hospitalization with a median hospital LOS of 11 days, 3 (19 %) required ICU and 3 (19 %) required mechanical ventilation. Among the 37 HTx recipients, 7 (19 %) died, 23 (62 %) required hospitalization with a median hospital LOS of 9 days, 6 (16 %) required ICU and 6 (16 %) required mechanical ventilation.

The majority of the 96 subjects in all three groups were male (HF-C/D = 65 %, LVAD = 69 %, HTx = 68 %). The most common comorbidities were hypertension (HF-C/D = 70 %, LVAD = 69 %, HTx = 87 %) and dyslipidemia (HF-C/D = 67 %, LVAD = 75 %, HTx = 65 %). Chronic kidney disease was most prevalent in the HTx group (HTx vs HF-C/D $p = 0.001$, HTx vs LVAD $p = 0.02$). In the LVAD cohort, diabetes was more common (HF-C/D = 54 %, LVAD = 75 %, and HTx = 41 %; LVAD vs HTx $p = 0.04$) as was COPD (HF-C/D = 7 %, LVAD = 69 %, and HTx = 8 %; LVAD vs HF-C/D $p < 0.001$, LVAD vs HTx $p < 0.001$). The mean body

Table 1
Baseline demographics and clinical characteristics of patients with stage C or D heart failure (HF-C/D), left ventricular assist devices (LVADs), and heart transplantation (HTx) diagnosed with COVID-19. Data presented as number (%) or mean ± SD. *P*-values derived from [a]Independent *t*-test or [b]Fisher's Exact Test.

	HF-C/D ($n = 43$, 45 %)	LVAD ($n = 16$, 17 %)	HTx ($n = 37$, 38 %)	*P*-value HF-C/D vs LVAD	*P*-value HF-C/D vs HTx	*P*-value LVAD vs HTx
Age – years	62 ± 13	58 ± 15	59 ± 16	0.32[a]	0.38[a]	0.68[a]
Gender:						
Male	28 (65.1 %)	11 (68.8)	25 (67.6)	–	–	–
Female	15 (34.9 %)	5 (31.2)	12 (32.4)	–	–	–
Race/ethnicity:						
Caucasian	32 (74.4 %)	10 (62.5)	26 (70.3)	–	–	–
African American	6 (14.0 %)	2 (12.5)	8 (21.6)	–	–	–
Other	4 (11.6 %)	4 (25.0)	3 (8.1)	–	–	–
Device type (for LVAD group only):						
HeartMate 3	–	11 (68.8)	–	–	–	–
HeartMate II	–	3 (18.8)	–	–	–	–
HeartWare	–	2 (12.5)	–	–	–	–
Hypertension	30 (69.8 %)	11 (68.8)	32 (86.5)	1.00[b]	0.11[b]	0.15[b]
Dyslipidemia	29 (67.4 %)	12 (75.0)	24 (64.9)	0.75[b]	0.82[b]	0.54[b]
Diabetes	23 (53.5 %)	12 (75.0)	15 (40.5)	0.23[b]	0.27[b]	**0.04**[b]
Chronic kidney disease	18 (41.9 %)	7 (43.8)	29 (78.4)	1.00[b]	**0.001**[b]	**0.02**[b]
Chronic obstructive pulmonary disease	3 (7.0 %)	11 (68.8)	3 (8.1)	**<0.001**[b]	1.00[b]	**<0.001**[b]
Coronary artery disease/transplant vasculopathy	21 (48.8 %)	11 (68.8)	12 (32.4)	0.24[b]	0.17[b]	0.19[b]
Body mass index – kg/m^2	30.1 ± 7.6	30.3 ± 6.5	30.2 ± 6.8	0.90[a]	0.94[a]	0.94[a]
Anticoagulation/antiplatelet medications	30 (69.8 %)	16 (100)	32 (86.5)	–	–	–
Immunosuppressive medications:						
Prednisone	3 (7.0 %)	0 (0)	27 (73.0)	–	–	–
Tacrolimus	0 (0)	0 (0)	30 (81.1)	–	–	–
Cyclosporine	2 (4.7 %)	0 (0)	4 (10.8)	–	–	–
Mycophenolate	0 (0)	0 (0)	18 (48.6)	–	–	–
Sirolimus	0 (0)	0 (0)	17 (45.9)	–	–	–

P-values in bold represent statistical significance ($p \leq 0.05$).

mass index (BMI) was similar among groups. Three patients from the HF-C/D cohort and one from the LVAD cohort were on oxygen prior to COVID-19 infection, but none from the HTx group. Before the diagnosis of COVID-19 was made, the LVAD group had an average of 2.4 years of device support (median = 2.3 years), while the mean time from HTx to COVID-19 diagnosis was 9.9 years (median = 5.6 years). Of the 96 patients, two contracted COVID-19 during their index hospitalization for LVAD placement and HTx.

Forty-nine of the 96 patients (51 %) with COVID-19 in this study were admitted to the hospital for further management [HF-C/D = 18 (37 %), LVAD = 8 (16 %), HTx = 23 (47 %)]. Tables 2 and 3 compare the clinical characteristics, therapies, and outcomes of hospitalized patients in each group. The median ICU LOS was significantly higher in HTx recipients when compared to HF-C/D (24 vs 10 days; $p = 0.04$), while LVAD patients fell in between (22 days). Patients who required hospitalization were older (64 ± 10 vs 56 ± 17 years: $p = 0.01$), had a higher incidence of hypertension (84 % vs 68 %), and significantly elevated levels of BUN (35 ± 21 vs 27 ± 13; $p = 0.05$) and creatinine (3.0 ± 4.0 vs 1.5 ± 0.6; $p = 0.03$) when compared to those who did not require hospitalization. No thromboembolic complications were observed in all three cohorts.

A total of 14 deaths occurred among the 96 patients (HF-C/D = 5, LVAD = 2, HTx = 7). As shown in Fig. 1, all deaths occurred within 50 days of COVID-19 diagnosis. The overall mortality rate at 90 days was higher in the HTx group (18.9 %) when compared to the LVAD (12.5 %) and HF-C/D (11.6 %) groups, although it was not statistically significant.

4. Discussion

The impact of COVID-19 on an individual, organizational, and societal level is enormous. This report is among the first to describe the impact of COVID-19 within a comprehensive, advanced heart failure practice. It highlights the challenges and key differences in outcomes within three groups of patients, stage C or D Heart Failure (HF-C/D), patients with Left Ventricular Assist Devices (LVADs) and those with Heart Transplantation (HTx).

This study confirms that all three cohorts of advanced HF patients who contracted COVID-19 are at increased risk for hospitalization and death. The overall in-hospital mortality for COVID-19 among all three cohorts was higher (28.6 %) than all patients without advanced HF (16.2 %) admitted to the study hospital during the same period. This ominous finding reinforces the importance of employing all COVID-19 preventive measures and mitigation strategies with advanced HF patients.

4.1. Impact on Stage C or D Heart Failure patients

The observed overall mortality rate in HF-C/D patients diagnosed with COVID-19 was 11.6 %. The in-hospital mortality in this cohort was 22.2 %. Risk of death in these patients was largely associated with compromised baseline health status and risk factors such as older age, coronary artery disease and obesity. These outcomes compare favorably to a previously reported in-hospital mortality in HF patients of 31.6 % [14]. Similarly, an analysis of 6439 patients hospitalized with COVID-19 identified a 40.0 % mortality rate among patients with HF in contrast to 24.9 % for those without HF [15].

Heart failure patients who were on the heart transplant waiting list were inactivated if they had a confirmed COVID-19 polymerase chain reaction (PCR) test or following a known exposure. Patients were reactivated upon confirmation of two consecutive negative PCR tests.

4.2. Impact on LVAD patients

This study demonstrated an overall 90-day mortality rate of 12.5 % in LVAD patients with COVID-19. This compares favorably to a previously reported mortality rate of 20% [16], especially when considering that the patients in this study had a greater incidence of comorbidities.

Table 2
Baseline clinical characteristics and therapies for hospitalized COVID-19 patients with stage C or D heart failure (HF-C/D), left ventricular assist devices (LVADs), and heart transplantation (HTx). Data presented as number (%) or mean ± SD (median). *P*-values derived from [a]Independent *t*-test, [b]Fisher's Exact Test or [c]Mann-Whitney *U* test.
CRP, C-reactive protein; BNP, B-type natriuretic peptide; BUN, blood urea nitrogen; ALT, alanine aminotransferase; AST, aspartate aminotransferase.

	HF-C/D (n = 18, 42 %)	LVAD (n = 8, 50 %)	HTx (n = 23, 62 %)	*P*-value HF-C/D vs LVAD	*P*-value HF-C/D vs HTx	*P*-value LVAD vs HTx
Age – years	68 ± 10	54 ± 10	64 ± 9	0.01[a]	0.16[a]	**0.04**[a]
Hypertension	13 (72.2 %)	7 (87.5)	21 (91.3)	0.63[b]	0.21[b]	1.00[b]
Dyslipidemia	14 (77.8 %)	7 (87.5)	15 (65.2)	1.00[b]	0.50[b]	0.38[b]
Diabetes	12 (66.7 %)	7 (87.5)	10 (43.5)	0.38[b]	0.21[b]	**<0.05**[b]
Chronic kidney disease	7 (38.9 %)	5 (62.5)	20 (87.0)	0.40[b]	0.002[b]	0.16[b]
Chronic obstructive pulmonary disease	1 (5.6 %)	7 (87.5)	3 (13.0)	**<0.001**[b]	0.62[b]	**<0.001**[b]
Coronary artery disease/transplant vasculopathy	12 (66.7 %)	7 (87.5)	6 (26.1)	0.38[b]	**0.01**[b]	**0.004**[b]
Body mass index – kg/m^2	32.6 ± 6.1	33.3 ± 5.7	29.3 ± 7.4	0.77[a]	0.06[a]	0.10[a]
White blood cells (×10^3/μL)	6.5 ± 3.3	8.5 ± 8.5	7.1 ± 4.9	0.56[a]	0.63[a]	0.70[a]
Neutrophil-to-lymphocyte ratio	11 ± 15 (5)	6 ± 6 (3.7)	11 ± 12 (7.9)	0.33[c]	0.69[c]	0.29[c]
Platelets (×10^3/μL)	208 ± 115	211 ± 78	188 ± 70	0.96[a]	0.52[a]	0.50[a]
CRP – mg/L	98.2 ± 76.7	46.1 ± 41.8	82.6 ± 70.6	0.08[a]	0.58[a]	0.15[a]
D-dimer – mg/L	2.4 ± 3.6 (1.1)	2.8 ± 2.1 (2.4)	1.4 ± 1.4 (0.7)	0.16[c]	0.45[c]	0.09[c]
BNP – pg/mL	837.4 ± 1003.3 (503)	506.4 ± 532 (297)	479.6 ± 931.3 (122)	0.75[c]	0.27[c]	0.11[c]
Troponin – ng/mL	0.16 ± 0.25 (0.08)	0.11 ± 0.13 (0.05)	0.15 ± 0.41 (0.01)	0.65[c]	0.03[c]	0.07[c]
BUN – mg/dL	33.4 ± 15.5	39.3 ± 35.9	35.3 ± 18.6	0.67[a]	0.73[a]	0.77[a]
Creatinine – mg/dL	1.9 ± 1.8	2.7 ± 3.8	3.9 ± 5.7	0.54[a]	0.12[a]	0.53[a]
Total Bilirubin – mg/dL	0.7 ± 0.4	0.7 ± 0.5	0.6 ± 0.3	0.81[a]	0.60[a]	0.56[a]
ALT – unit/L	28.5 ± 22.9	32.4 ± 22.1	26.2 ± 14.9	0.69[a]	0.72[a]	0.48[a]
AST – unit/L	41.1 ± 38.9	36 ± 23.8	32.9 ± 17.8	0.69[a]	0.43[a]	0.74[a]
Medications received:						
Dexamethasone	14 (77.8 %)	4 (57.1)	17 (73.9)	–	–	–
Convalescent plasma	11 (61.1 %)	4 (57.1)	12 (52.2)	–	–	–
Remdesivir	8 (44.4 %)	2 (28.6)	9 (39.1)	–	–	–

P-values in bold represent statistical significance ($p \leq 0.05$).

Table 3
Outcomes and treatment of hospitalized COVID-19 patients with stage C or D heart failure (HF-C/D), left ventricular assist devices (LVADs), and heart transplantation (HTx). Data presented as number (%) or mean ± SD (median). *P*-values derived from [a]Fisher's Exact Test, [b]Mann-Whitney *U* test or [c]Log-rank test generated by Kaplan-Meier analysis.
HLOS, hospital length of stay; ICU, Intensive care unit.

	HF-C/D (*n* = 18, 42 %)	LVAD (*n* = 8, 50 %)	HTx (*n* = 23, 62 %)	*P*-value HF-C/D vs LVAD	*P*-value HF-C/D vs HTx	*P*-value LVAD vs HTx
Oxygen prior to hospitalization	3 (16.7 %)	1 (12.5)	0 (0)	0.53[a]	–	–
Oxygen requirement during hospitalization (including mechanical ventilation)	15 (83.3 %)	5 (62.5)	16 (69.6)	0.33[a]	0.47[a]	1.00[a]
Mechanical ventilation	4 (22.2 %)	3 (42.9)	6 (26.1)	0.64[a]	1.00[a]	0.66[a]
Oxygen requirement at discharge	8 (44.4 %)	3 (37.5)	4 (17.4)	1.00[a]	0.09[a]	0.34[a]
Thromboembolic events	0 (0)	0 (0)	0 (0)	–	–	–
Total HLOS	11 ± 12 (7)	22 ± 26 (11)	16 ± 17 (9)	0.29[b]	0.61[b]	0.60[b]
ICU LOS	12 ± 12 (10)	22 ± 4 (22)	26 ± 10 (24)	0.25[b]	**0.04**[b]	0.50[b]
90-day mortality	11.6 % (*n* = 5)	12.5 % (*n* = 2)	18.9 % (*n* = 7)	0.98[c]	0.44[c]	0.60[c]

P-values in bold represent statistical significance ($p \leq 0.05$).

Despite the correction of left ventricular dysfunction with LVAD support, these patients carry a burden of risk due to underlying comorbidities not corrected by the device. These comorbidities included dyslipidemia, diabetes, and COPD. Of note, the mortality for LVAD patients not infected with COVID-19 was 7.9 % over the course of the study.

4.3. Impact on heart transplant recipients

An overall 90-day mortality of 18.9 % was observed in HTx recipients diagnosed with COVID-19. This is lower than previously reported mortality (25–30 %) [12,13]. Of note, the mortality for HTx patients not infected with COVID-19 was 8.1 % over the course of the study. Chronic immunosuppression results in increased and prolonged COVID-19 viral loads resulting in heightened infectivity and poor prognosis [12]. Patients with solid organ transplant in general are at increased risk of severe illness and mortality when compared to the general population [17]. Hospitalization rates of 32–78% [18] and mortality rates as high as 30 % were reported early in the pandemic [12].

During the time patients received COVID-19 therapies, immunosuppressive agents were adjusted. The doses of Sirolimus or Calcineurin inhibitors (CNI), such as Tacrolimus or Cyclosporine, were reduced by 30–50 % and their levels were monitored daily. Patients on Mycophenolate had their doses held for a minimum of ten days, and then dosing was restarted after the COVID-19 infection was well controlled. Steroids were continued throughout the COVID-19 infection and Dexamethasone was given in accordance with COVID-19 treatment guidelines.

A joint statement by the American Society of Transplantation, International Society for Heart and Lung Transplantation, and American Society of Transplant Surgeons recommends that all solid organ transplant recipients be vaccinated against SARS-CoV-2 [19]. A third dose of the vaccine is recommended for solid-organ transplant recipients as it significantly improves the immunogenicity of the vaccine [12,20].

4.4. Comparing HF-C/D vs LVAD vs HTx patients

Hospitalization and mortality rates trended higher among HTx recipients as compared to LVAD and HF-C/D patients. Increased mortality in HTx recipients (18.9 %) may be due to a greater degree of viral replication and delayed clearance expected with immunosuppression [17]. Of note, the overall mortality rate associated with COVID-19 in advanced HF patients with or without mechanical circulatory support was comparable (HF-C/D = 11.6 % and LVAD = 12.5 %). The overall mortality risk for HF-C/D patients receiving LVADs is expected to be lowered by relieving symptomatic HF. The potential benefit of an LVAD

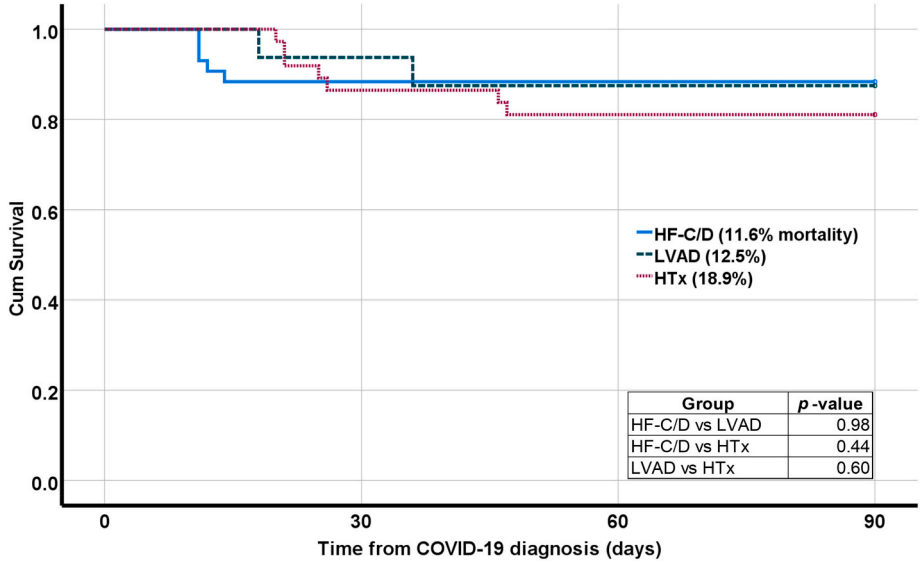

Fig. 1. Ninety-day Kaplan-Meier (KM) survival curves for stage C or D heart failure (HF-C/D), left ventricular assist devices (LVADs), and heart transplantation (HTx) patients diagnosed with COVID-19.

may be offset, however, by the greater prevalence of comorbidities in the LVAD group including COPD (LVAD = 69 %, HF-C/D = 7 %) and an increased need for mechanical ventilation (LVAD = 42.9 % and HF-C/D = 22.2 %). Previous reports have demonstrated an increased risk of thrombotic events among COVID-19 patients [21]. In this study, the majority of patients in all three groups (HF = 70 %, LVAD = 100 %, HTx = 87 %; Table 1) were on anticoagulation or antiplatelet medications and no thromboembolic complications were noted during the study period. Careful clinical screening for thromboembolic events was done in all patients and formal testing was reserved for those with clinical indications. Patients who were hospitalized received treatment based on practice guidelines available during the study period (Table 3).

4.5. Implications of this study

The impact of morbidity, mortality and the burden to patients, families and caregivers should serve as a strong incentive to prioritize all possible preventive and therapeutic options. Critical steps in controlling COVID-19 include education, isolation, prevention, controlling the transmission, and timely treatment [22]. Vaccination against COVID-19 is an effective and safe way of protecting people [23,24]. As further confirmed in this study, patients with advanced heart failure are at increased risk of death if they contract COVID-19.

It is possible that our results, which compare favorably with others, may be due to earlier intervention enabled by close follow up and monitoring, and the dedicated around-the-clock medical support provided by this program.

4.6. Limitations

The generalizability of this study for other HF programs is uncertain, given that this was a single center study. While this review attempted to include every patient diagnosed with COVID-19 in the program, some HF patients may not have been detected across the expansive geographic distribution that the program serves. Hospitalizations may have occurred at separate centers which were not brought to attention despite rigorous attempts and efforts to track all patients.

Since its inception, COVID-19 has evolved, with mutations representing differing risks with infection and with increasingly effective therapeutic tools introduced to the clinical setting. This study includes patients throughout this evolution and may not accurately represent outcomes in the current era. Nevertheless, this report should serve as a baseline for future studies comparing the early COVID-19 experience to that which is more contemporary.

4.7. Conclusion

This report is among the first to describe the impact of COVID-19 within a comprehensive, advanced HF practice. It highlights the risks of morbidity and mortality associated with COVID-19 experienced by the stage C or D HF population, LVAD patients and HTx recipients. A 90-day mortality rate of 19 % with heart transplant patients acquiring COVID-19 is ominous. Likewise, the 90-day mortality rate of 12 % for both stage C or D HF and LVAD patients infected with COVID-19 represents substantial risk, well above a 1–4 % risk of death for a population of a similar age range infected with COVID-19. These findings should serve as a reminder of the importance of employing all preventative and therapeutic options to protect these patients who carry serious risks greater than those of the general population is an essential imperative.

CRediT authorship contribution statement

SG conceived the study; SG, LCC, DPN, DAH, JWL and AMB acquired, analyzed, and interpreted the data; SG, LCC, JWL and AMB wrote the manuscript with inputs from all authors.

These findings were presented in oral presentation format at the 42nd annual meeting of the International Society for Heart and Lung Transplant in April 2022, Boston, Massachusetts.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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