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Outcomes related to hospital characteristics of heart transplant centers: A National Readmission Database analysis

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outcomes;
center characteristics;
mortality;
care efficiency

BACKGROUND: This study showcases an analysis performed using the National Readmission Database (NRD) from 2016 to 2019 to analyze the impact of ownership, location, size, and teaching status of transplant centers on cardiac transplant outcomes.
METHODS: Demographic variables and hospital characteristics were identified using NRD data and International Classification of Diseases,10th revision codes. Comorbidities were assessed using the Elixhauser comorbidity index. Multivariable linear and logistic regression analyses were used to assess in-hospital mortality, 30-day and 180-day readmission rates, length of stay, days from admission to procedure, transfer to a rehab center, graft rejection, graft failure, and index admission total cost.
RESULTS: Most cardiac transplants occurred in privately owned, large metropolitan areas, large bed size, and teaching centers. No significant difference was seen in in-hospital mortality, graft rejection, or graft failure by hospital ownership, location, size, or teaching status. Patients in private hospitals were more likely to be readmitted at 180 days and less likely to be transferred to rehab center compared to government-owned hospitals. Patients in private, small bed size, and teaching centers were more likely to have shorter length of stay. Additionally, days of admission to procedure were shorter in small bed size and teaching centers. Furthermore, the cost of index-hospital stay was higher in privately owned, large metropolitan areas, large bed size, and teaching centers.

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CONCLUSIONS: While in-hospital mortality was not significantly different, various other outcomes related to cost and efficiency seem to be impacted by hospital characteristics.
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Background

The number of patients receiving heart transplants has increased 61.9% in the last 2 decades with over 250 transplant centers currently performing this life-saving procedure across the United States (US).[1,2] There are now more transplant centers that are nonmetropolitan, government-owned, and located in smaller medical centers. As the heterogeneity of centers increases, understanding how center characteristics impact outcome becomes important. As seen in other fields, such as kidney transplantation, cardiogenic shock management, and interventional cardiology procedures, a center's characteristics can impact outcomes.[3-5] Characteristics, such as ownership, location, size, and teaching status, can impact a center's policy and mission statement and have been associated with outcomes in advanced heart failure patients receiving left ventricular assist device (LVAD).[6,7] The goal of this study was to evaluate the impact of transplant center characteristics on cardiac transplantation outcomes. To study the impact of ownership, location, size, and teaching status of a transplant center on cardiac transplantation outcomes, we used data from the National Readmission Database (NRD), a publicly available dataset. Furthermore, utilization of mechanical support devices by different hospital characteristics and their impact on our outcomes were evaluated in a subanalysis of this study. This study hypothesizes outcomes after heart transplant are worse in government-owned, nonmetropolitan, small, and nonteaching health care systems.

Methodology

Data source

The NRD is one of the datasets maintained by the Agency for Healthcare Research and Quality as a part of the Healthcare Cost and Utilization Project. This dataset is an annual database using the discharge data drawn from the Healthcare Cost and Utilization Project state inpatient databases. Each patient has a verified linkage number which is used to track the patients across hospitals within a state during a given year. The NRD database is one of the largest publicly available databases in the US, including patients from all-payer sources. It provides longitudinal information about a patient's initial hospitalization and subsequent readmissions. It contains a weighted sample of hospitalizations in the US and can be used to derive national estimates of various hospitalizations directly. The database also provides International Classification of Diseases, 10th revision (ICD-10) codes for diagnoses and procedures and includes meaningful clusters of similar conditions called the Clinical Classifications Software. It also provides an assessment of the Elixhauser comorbidities and reliably tracks patients for readmissions. The NRD data provides the information from January 1 to December 31 in a calendar year. We analyzed this dataset between the years 2016 and 2019. This study was exempted from institutional review board approval as NRD database is limited and contains deidentified patient information. All data and materials are available from the corresponding author on request.

Study population

All hospitalizations for cardiac transplantation from 2016 to 2019 were identified by using ICD-10-PSC code 02YA0Z0. All patients less than 18 years of age were excluded. Furthermore, all patients who received multiorgan transplantation (liver, lung, kidney, intestine) were excluded using the appropriate ICD-10-PCS codes (Table S1).

Variables

Patient demographics, such as age, sex, insurance payer (Medicare, Medicaid, private insurance, self-pay), and median household income (lowest, middle low, middle high, highest) were identified using NRD variables. Additionally, hospital ownership (governmental, private), hospital location (small metropolitan [< 1 million residents], large metropolitan [≥1 million residents]), hospital bed size (small, medium, large), and teaching status (teaching, nonteaching) were also identified. Hospital characteristics in the NRD are collected through the American Hospital Association Annual Survey.[8] Furthermore, we stratify patients by type of mechanical circulatory support (MCS), for example, LVAD, extracorporeal membrane oxygenation (ECMO), intra-aortic balloon pump (IABP), Impella, they received during their index transplant hospitalization by using ICD-10-PSC codes. Comorbidities of patients were identified using the I10_DXn variable by using ICD-10. To assess a patient's overall comorbidity, the Elixhauser comorbidity index was used.

Outcomes of interest

Outcomes of interest were in-hospital mortality, 30-day readmission, 180-day readmission, length of stay during index hospitalization, days from admission to procedure, transfer to rehab center, graft rejection, and graft failure. For the analyses of the 30-day and 180-day readmission outcomes, we excluded patients who received the heart transplant (index hospitalization) in December (for 30-day readmission analysis) or from July through December (for 180-day readmission analysis) given that patient identifiers cannot be linked across years in the NRD. Graft function was evaluated by looking at graft rejection and graft failure using appropriate ICD-10 diagnosis codes. Cost was assessed by evaluating the index admission total charge, which is a variable available in the NRD database.

Statistical analysis

All analyses were conducted with weighted data using the provided weight variable (discharge-level weight). Patient characteristics and outcomes were reported as frequencies and proportions for categorical variables and as median and interquartile range (IQR) or mean and standardized deviation for continuous variables as appropriate. Differences between groups (extended criteria vs standard criteria) were compared using the chi-square or Fisher's exact test for categorical variables and Kruskal-Wallis test or *t*-test for the continuous variables as appropriate. Line graphs were used to depict the trend of select outcomes by hospital type and year. The trends of outcomes over time were evaluated within and between groups using the nonparametric trend test (*nptrend*). Logistic regression was used to determine factors associated with the outcomes. The selection of covariates for the multivariable models was based on both the clinical importance and the least absolute shrinkage and selection operator method with the cross-validation selection option.[9,10] The multivariate model included age, sex, primary payer, median house hold income, comorbidities, type of MCS, and hospital-level variables. All the analyses were performed on Stata version 17.0 (StataCorp LLC, College Station, TX). A *p*-value of <0.05 was considered statistically significant.

Results

Demographic and clinical characteristics

From 2016 to 2019, 11,539 patients were identified to have received cardiac transplantation (Figure 1). Median age of the cohort was 56 years (IQR: 46-63 years) and 72.8% were male. Insurance coverage was categorized into private insurance (43.1%), Medicare (38.3%), Medicaid (12.0%), and self-pay (6.5%). At the time of transplant, 24.4% were bridged with an LVAD, 19.8% an IABP, 3.8% an ECMO, and 3.3% an Impella. Various baseline characteristics were significantly different across the various hospital characteristics and are detailed in Table 1.

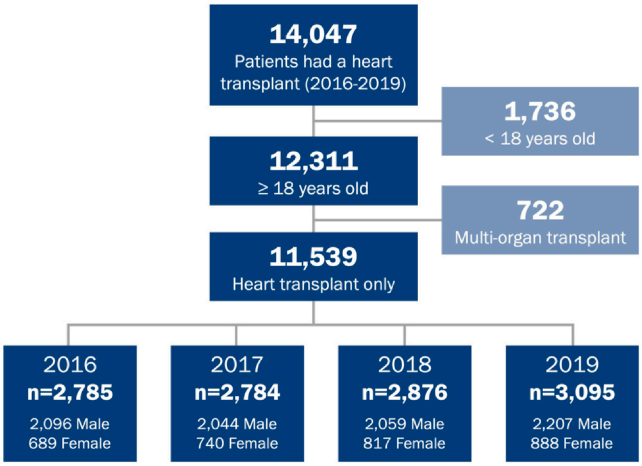

Figure 1 Patient selection flowchart.

Outcomes based on hospital characteristics

Hospital ownership

A majority (83.9%) of the transplants were performed in privately owned hospitals (9,687 patients). There was no significant difference in-hospital mortality between private and public ownerships but both 30-days and 180-day readmission were significantly higher in private hospitals compared to government (30 days: 7.2% vs 5.1%, $p=0.002$) and 180 days: 40.9% vs 34.1%, $p < 0.001$) (Table 2). Most common primary payers in either ownership category were private insurance. Private hospitals had a lower length of stay compared to government hospitals (25 days vs 26 days, $p=0.004$). No significant difference was seen for the index admission cost, graft rejection and graft failure between the 2 groups. There was no association between hospital ownership and in-hospital mortality in univariable (Table S2) and multivariable logistic regression models (Table S3). While the multivariable logistic regression showed greater odds of 180-day readmission in privately owned hospitals (Figure 2), patients in private hospitals had a shorter length of stay (Figure 3) in both univariable (Table S4) and multivariable (Table S5) linear regression models. Patients in government hospitals were more likely to be transferred to rehab centers in both univariable and multivariable regression analyses.

Hospital size

Number of patients who received a heart transplant in small, medium, and large hospitals, respectively, were 184 (1.59%), 654 (5.6%), and 10,701 (92.7%). In-hospital mortality was 8.7% in the small hospital group compared to 3.7% and 5.4% in medium and large hospitals ($p=0.02$). Large hospitals had lower 30-day readmission rate at 6.6% when compared to medium and small hospitals (6.6% vs 10% vs 8.1%, $p=0.01$). However, small hospitals had a lower 180-day readmission rate at 35% when compared to medium and large hospitals (35% vs 48.6% vs 39.4%, $p=0.004$). Additionally, patients were more likely to be transferred to rehab centers in small hospitals at 14.2% vs medium hospitals and large hospitals (14.2% vs 4.8 vs 5.3%, $p < 0.001$). Most common primary payer in small hospitals was Medicare which was contrary to the medium and large hospitals where private insurers were more common. Length of stay was 25 days in large hospitals compared to 22 and 23 days in medium and small hospitals, respectively ($p=0.004$). Transplant episode cost was

Table 1 Patient Characteristics, Heart Transplant Recipients in NRD Database, 2016 to 2019

Variable	By hospital type				y hospital location			By teaching hospital			By hospital bed size			
	Total (N = 11,539)	Government hospital (*n* = 1,852)	Private hospital (*n* = 9,687)	*p*-value	Small metropolitan (*n* = 1,555)	Large metropolitan (*n* = 9,984)	*p*-value	Nonteaching (*n* = 123)	Teaching (*n* = 11,416)	*p*-value	Small (*n* = 184)	Medium (*n* = 654)	Large (*n* = 10,701)	Overall *p*-value
Age at surgery (years), median (IQR)	56 (46, 63)	55 (42, 62)	57 (47, 64)	0.004	57 (47, 64)	56 (46, 63)	0.30	53 (42, 60)	56 (46, 63)	0.09	60 (49, 66)	58 (46, 64)	56 (46, 63)	< 0.001
Gender				0.04			0.10			0.75				0.12
Male	8,405 (72.8)	1,312 (70.8)	7,093 (73.2)		1,106 (71.1)	7,299 (73.1)		88 (71.3)	8,318 (72.9)		144 (71.3)	487 (72.9)	7,774 (72.8)	
Female	3,134 (27.2)	540 (29.2)	2,594 (26.8)		449 (28.9)	2,685 (26.9)		35 (28.7)	3,099 (27.1)		39 (28.7)	167 (27.1)	2,928 (27.2)	
Payer				< 0.001			< 0.001			0.01				< 0.001
Medicare	4,396 (38.3)	682 (36.8)	3,714 (38.6)		606 (39)	3,790 (38.2)		50 (40.9)	4,346 (38.3)		93 (50.6)	245 (37.5)	4,058 (38.2)	
Medicaid	1,379 (12)	326 (17.6)	1,053 (11)		195 (12.5)	1,184 (11.9)		21 (16.7)	1,358 (12)		13 (7.2)	63 (9.6)	1,303 (12.3)	
Private insurance	4,946 (43.1)	708 (38.3)	4,237 (44.1)		604 (38.8)	4,342 (43.8)		51 (41.4)	4,895 (43.1)		75 (40.9)	296 (45.2)	4,575 (43)	
Self-pay/no charge/other	746 (6.5)	136 (7.3)	610 (6.3)		151 (9.7)	595 (6)		1 (1.1)	745 (6.6)		2 (1.3)	51 (7.8)	693 (6.5)	
Median household income (percentile)				< 0.001			< 0.001			0.75				0.004
Lowest (0-25th)	2,730 (23.9)	435 (23.7)	2,295 (23.9)		402 (26.1)	2,328 (23.6)		34 (28.2)	2,696 (23.9)		44 (24.9)	168 (26.1)	2,518 (23.8)	
Middle low (26th-50th)	2,931 (25.7)	416 (22.7)	2,515 (26.2)		525 (34.1)	2,406 (24.4)		26 (21.2)	2,905 (25.7)		41 (23.1)	181 (28.1)	2,709 (25.6)	
Middle high (51th-75th)	2,987 (26.2)	550 (30)	2,437 (25.4)		399 (25.9)	2,588 (26.2)		31 (25.5)	2,956 (26.2)		45 (25.0)	184 (28.6)	2,758 (26.0)	
Highest (76th-100th)	2,769 (24.3)	434 (23.6)	2,336 (24.4)		213 (13.8)	2,557 (25.9)		31 (25.1)	2,739 (24.2)		48 (26.9)	111 (17.2)	2,611 (24.6)	
Elixhauser index, mean (± SD)	6.8 (± 2.0)	6.6 (± 1.9)	6.8 (± 2.1)	0.01	6.3 (± 2.3)	6.8 (± 2.0)	< 0.001	5.8 (± 2.0)	6.8 (± 2.0)	< 0.001	8.0 (± 1.9)	6.3 (± 2.1)	6.8 (± 2.0)	0.20
Comorbidities														
Congestive heart failure	11,447 (99.2)	1,838 (99.2)	9,610 (99.2)	0.83	1,518 (97.6)	9,929 (99.4)	< 0.001	120 (97.8)	11,327 (99.2)	0.04	184 (100)	653 (99.8)	10,611 (99.2)	0.18
Cardiac arrhythmias	8,528 (73.9)	1,375 (74.2)	7,153 (73.8)	0.72	1,029 (66.1)	7,499 (75.1)	< 0.001	60 (48.8)	8,468 (74.2)	< 0.001	151 (82.4)	458 (69.9)	7,919 (74.0)	0.002
Valvular disease	2,530 (21.9)	395 (21.3)	2,135 (22.0)	0.50	246 (15.8)	2,284 (22.9)	< 0.001	24 (19.8)	2,506 (21.9)	0.52	55 (29.9)	115 (17.5)	2,360 (22.1)	0.001
Pulmonary circulation disorders	3,778 (32.7)	617 (33.3)	3,160 (32.6)	0.56	437 (28.1)	3,341 (33.5)	< 0.001	28 (22.4)	3,750 (32.8)	0.02	95 (51.5)	183 (27.9)	3,500 (32.7)	< 0.001
Peripheral vascular disorders	5,689 (49.3)	901 (48.6)	4,788 (49.4)	0.54	716 (46.0)	4,973 (49.8)	0.01	54 (43.5)	5,636 (49.4)	0.23	127 (69)	324 (49.5)	5,239 (49)	< 0.001
Hypertension, uncomplicated	1,061 (9.2)	211 (11.4)	850 (8.8)	< 0.001	192 (12.4)	869 (8.7)	< 0.001	8 (6.7)	1,053 (9.2)	0.30	9 (5.0)	51 (7.8)	1,001 (9.4)	0.053
Hypertension, complicated	7,629 (66.1)	1,060 (57.2)	6,570 (67.8)	< 0.001	954 (61.3)	6,675 (66.9)	< 0.001	84 (68.3)	7,545 (66.1)	0.61	122 (66.5)	423 (64.6)	7,085 (66.2)	0.69
Paralysis	243 (2.1)	34 (1.8)	209 (2.2)	0.38	33 (2.1)	209 (2.1)	0.94	3 (2.2)	240 (2.1)	0.80	9 (4.7)	8 (1.2)	226 (2.1)	0.01
Other neurological disorders	1,455 (12.6)	204 (11)	1,251 (12.9)	0.02	168 (10.8)	1,287 (12.9)	0.02	20 (16.3)	1,435 (12.6)	0.22	37 (20.3)	84 (12.8)	1,334 (12.5)	0.01
Chronic pulmonary disease	1,459 (12.6)	190 (10.3)	1,269 (13.1)	0.001	227 (14.6)	1,232 (12.3)	0.01	12 (9.6)	1,447 (12.7)	0.33	31 (16.8)	79 (12.1)	1,349 (12.6)	0.21
Diabetes	3,676 (31.9)	528 (28.5)	3,148 (32.5)	0.001	459 (29.5)	3,216 (32.2)	0.03	31 (25.4)	3,644 (31.9)	0.11	61 (33.4)	201 (30.8)	3,413 (31.9)	0.75
Hypothyroidism	1,636 (14.2)	253 (13.7)	1,382 (14.3)	0.49	255 (16.4)	1,381 (13.8)	0.01	16 (12.8)	1,620 (14.2)	0.71	34 (18.4)	85 (13)	1,517 (14.2)	0.17
Renal failure	5,000 (43.3)	763 (41.2)	4,237 (43.7)	0.04	553 (35.6)	4,447 (44.5)	< 0.001	47 (38.2)	4,953 (43.4)	0.25	84 (46)	217 (33.1)	4,699 (43.9)	< 0.001
Liver disease	1,572 (13.6)	262 (14.2)	1,310 (13.5)	0.47	159 (10.2)	1,413 (14.2)	< 0.001	19 (15.1)	1,554 (13.6)	0.56	31 (17.1)	71 (10.9)	1,469 (13.7)	0.048
Peptic ulcer disease excluding bleeding	69 (0.6)	7 (0.4)	62 (0.6)	0.18	2 (0.1)	66 (0.7)	0.01	0 (0.0)	69 (0.6)	1.00	2 (1.0)	5 (0.7)	62 (0.6)	0.35
AIDS/HIV	10 (0.1)	2 (0.1)	8 (0.1)	0.67	0 (0.0)	10 (0.1)	0.21	0 (0.0)	10 (0.1)	1.00	0 (0.0)	0 (0.0)	10 (0.1)	1.00
Lymphoma	75 (0.7)	4 (0.2)	71 (0.7)	0.01	9 (0.6)	66 (0.7)	0.71	0 (0.0)	75 (0.7)	1.00	2 (0.9)	8 (1.2)	66 (0.6)	0.09
Metastatic cancer	1 (0.0)	0 (0.0)	1 (0.0)	1.00	0 (0.0)	1 (0)	1.00	0 (0.0)	1 (0.0)	1.00	0 (0.0)	0 (0.0)	1 (0.0)	1.00
Solid tumor without metastasis	44 (0.4)	7 (0.4)	37 (0.4)	0.10	5 (0.3)	39 (0.4)	0.68	0 (0.0)	44 (0.4)	1.00	4 (2.0)	6 (1.0)	34 (0.3)	0.001
Rheumatoid arthritis/collagen vascular	225 (1.9)	42 (2.2)	183 (1.9)	0.28	27 (1.8)	198 (2)	0.51	5 (4.4)	220 (1.9)	0.09	3 (1.9)	10 (1.6)	211 (2)	0.78
Coagulopathy	6,127 (53.1)	1,009 (54.5)	5,118 (52.8)	0.19	964 (62)	5,163 (51.7)	< 0.001	50 (40.5)	6,077 (53.2)	0.01	116 (63)	312 (47.7)	5,700 (53.3)	0.00
Obesity	1,478 (12.8)	224 (12.1)	1,255 (13)	0.31	158 (10.2)	1,320 (13.2)	0.001	15 (12.3)	1,463 (12.8)	0.84	42 (23)	96 (14.7)	1,340 (12.5)	< 0.001
Weight loss	2,429 (21)	360 (19.5)	2,068 (21.4)	0.07	211 (13.6)	2,218 (22.2)	< 0.001	11 (8.5)	2,418 (21.2)	0.001	57 (31.1)	112 (17.1)	2,260 (21.1)	< 0.001
Fluid and electrolyte disorders	8,681 (75.2)	1,291 (69.7)	7,390 (76.3)	< 0.001	1,141 (73.3)	7,541 (75.5)	0.06	77 (62.5)	8,604 (75.4)	0.001	166 (90.5)	465 (71.1)	8,050 (75.2)	< 0.001
Blood loss anemia	202 (1.8)	44 (2.4)	158 (1.6)	0.03	19 (1.2)	184 (1.8)	0.08	1 (1)	201 (1.8)	0.73	2 (1.0)	8 (1.3)	192 (1.8)	0.60
Deficiency anemia	760 (6.6)	159 (8.6)	601 (6.2)	< 0.001	64 (4.1)	697 (7)	< 0.001	6 (5)	754 (6.6)	0.44	9 (4.8)	34 (5.2)	717 (6.7)	0.21

(*continued on next page*)

Table 1 (*Continued*)

Variable	By hospital type				y hospital location			By teaching hospital			By hospital bed size			
	Total (N = 11,539)	Government hospital (*n* = 1,852)	Private hospital (*n* = 9,687)	*p*-value	Small metropolitan (*n* = 1,555)	Large metropolitan (*n* = 9,984)	*p*-value	Nonteaching (*n* = 123)	Teaching (*n* = 11,416)	*p*-value	Small (*n* = 184)	Medium (*n* = 654)	Large (*n* = 10,701)	Overall *p*-value
Alcohol abuse	193 (1.7)	37 (2)	155 (1.6)	0.22	18 (1.2)	174 (1.7)	0.09	1 (1.1)	191 (1.7)	0.46	8 (4.1)	7 (1)	178 (1.7)	0.02
Drug abuse	222 (1.9)	31 (1.7)	191 (2)	0.39	20 (1.3)	203 (2.0)	0.046	0 (0.0)	222 (1.9)	0.18	2 (1.1)	8 (1.2)	212 (2)	0.35
Psychoses	50 (0.4)	11 (0.6)	39 (0.4)	0.25	5 (0.3)	45 (0.5)	0.47	0 (0.0)	50 (0.4)	1.00	2 (0.9)	2 (0.2)	47 (0.4)	0.33
Depression	1,752 (15.2)	281 (15.2)	1,471 (15.2)	0.99	227 (14.6)	1,525 (15.3)	0.49	17 (13.5)	1,735 (15.2)	0.67	18 (9.6)	68 (10.4)	1,666 (15.6)	< 0.001
Any LVAD	2,814 (24.4)	419 (22.6)	2,395 (24.7)	0.054	384 (24.7)	2,430 (24.3)	0.76	32 (25.8)	2,782 (24.4)	0.67	17 (9.1)	221 (33.8)	2,576 (24.1)	< 0.001
Any LVAD at same hospital	538 (4.7)	103 (5.6)	435 (4.5)	0.045	82 (5.3)	456 (4.6)	0.22	6 (5.2)	532 (4.7)	0.91	18 (9.9)	27 (4.1)	493 (4.6)	0.003
Any ECMO	442 (3.8)	89 (4.8)	353 (3.6)	0.02	64 (4.1)	378 (3.8)	0.53	3 (2.6)	439 (3.8)	0.42	7 (4)	27 (4.1)	408 (3.8)	0.92
Any Impella	376 (3.3)	86 (4.6)	290 (3)	< 0.001	42 (2.7)	334 (3.3)	0.18	2 (1.3)	374 (3.3)	0.31	12 (6.8)	22 (3.3)	342 (3.2)	0.04
Any balloon pump	2,280 (19.8)	319 (17.2)	1,961 (20.2)	0.003	205 (13.2)	2,075 (20.8)	< 0.001	17 (14.1)	2,262 (19.8)	0.10	44 (23.7)	80 (12.2)	2,157 (20.2)	< 0.001
Patient location				0.10			< 0.001			0.30				0.14
Nonmetropolitan	1,683 (14.6)	247 (13.3)	1,437 (14.8)		497 (32.0)	1,186 (11.9)		22 (18.1)	1,661 (14.6)		20 (11.1)	108 (16.5)	1,555 (14.5)	
Metropolitan	9,856 (85.4)	1,605 (86.7)	8,251 (85.2)		1,058 (68.0)	8,798 (88.1)		101 (81.9)	9,755 (85.4)		163 (88.9)	546 (83.5)	9,146 (85.5)	
Hospital type							< 0.001			0.19				< 0.001
Government	–	–	–		322 (20.7)	1,530 (15.3)		0 (0.0)	1,852 (16.2)		0 (0.0)	0 (0.0)	1,852 (17.3)	
Private	–	–	–		1,233 (79.3)	8,454 (84.7)		123 (100)	9,564 (83.8)		184 (100)	654 (100)	8,849 (82.7)	
Hospital location				< 0.001						< 0.001				< 0.001
Small metropolitan areas < 1 M residents	1,555 (13.5)	322 (17.4)	1,233 (12.7)		–	–	–	2 (1.8)	1,553 (13.6)		2 (1.3)	3 (0.5)	1,550 (14.5)	
Large metropolitan areas ≥1 M residents	9,984 (86.5)	1,530 (82.6)	8,454 (87.3)		–	–	–	121 (98.2)	9,863 (86.4)		181 (98.7)	651 (99.5)	9,152 (85.5)	
Bed size				< 0.001			< 0.001			0.002				
Small	184 (1.6)	0 (0.0)	184 (1.9)		2 (0.2)	181 (1.8)		0 (0.0)	184 (1.6)		–	–	–	–
Medium	654 (5.7)	0 (0.0)	654 (6.8)		3 (0.2)	651 (6.5)		0 (0.0)	654 (5.7)		–	–	–	–
Large	10,701 (92.7)	1,852 (100)	8,849 (91.3)		1,550 (99.6)	9,152 (91.7)		123 (100)	10,579 (92.7)		–	–	–	–
Teaching hospital				< 0.001			< 0.001							0.002
Metropolitan nonteaching	123 (1.1)	0 (0)	123 (1.3)		2 (0.1)	121 (1.2)		–	–	–	0 (0)	0 (0)	123 (1.1)	
Metropolitan teaching	11,417 (98.9)	1,852 (100)	9,564 (98.7)		1,553 (99.9)	9,863 (98.8)		–	–	–	184 (100)	654 (100)	10,579 (98.9)	
Discharge year				0.01			< 0.001			< 0.001				0.33
2016	2,785 (24.1)	474 (25.6)	2,311 (23.9)		453 (29.1)	2,331 (23.4)		22 (18)	2,763 (24.2)		44 (24.1)	177 (27)	2,564 (24)	
2017	2,784 (24.1)	388 (21)	2,396 (24.7)		371 (23.8)	2,413 (24.2)		56 (45.5)	2,728 (23.9)		47 (25.4)	138 (21.1)	2,599 (24.3)	
2018	2,875 (24.9)	468 (25.3)	2,407 (24.9)		324 (20.8)	2,552 (25.6)		26 (20.9)	2,850 (25)		46 (24.9)	175 (26.8)	2,655 (24.8)	
2019	3,095 (26.8)	522 (28.2)	2,573 (26.6)		408 (26.2)	2,687 (26.9)		19 (15.6)	3,076 (26.9)		47 (25.6)	165 (25.2)	2,883 (26.9)	

Abbreviations: AIDS, Aquired Immunodeficiency Syndrome; ECMO, extracorporeal membrane oxygenation; HIV, Human Immunodeficiency Virus; IQR, interquartile range; LVAD, left ventricular assist device; NRD, National Readmission Database; SD, standardized deviation.

Values are in frequency and % unless otherwise specified.

Table 2 Outcome Summary by Hospital Characteristics

Outcome/Variable	Number with available data	By hospital type: Total (N = 11,539)	Government hospital (n = 1,852)	Private hospital (n = 9,687)	p-value	By hospital location: Small metropolitan (n = 1,555)	Large metropolitan (n = 9,984)	p-value	By teaching hospital: Nonteaching (n = 123)	Teaching (n = 11,416)	p-value	By hospital bed size: Small (n = 184)	Medium (n = 654)	Large (n = 10,701)	Overall p-value
In-hospital mortality	11,539	612 (5.3)	102 (5.5)	511 (5.3)	0.68	106 (6.8)	506 (5.1)	0.004	6 (4.8)	606 (5.3)	0.83	16 (8.7)	24 (3.7)	572 (5.4)	0.02
30-day readmission, all-cause	10,605	727 (6.9)	88 (5.1)	640 (7.2)	0.002	117 (8.3)	610 (6.6)	0.03	10 (8.8)	717 (6.8)	0.45	14 (8.1)	60 (10.0)	653 (6.6)	0.01
180-day readmission, all-cause	5,585	2,221 (39.8)	307 (34.1)	1,914 (40.9)	< 0.001	267 (36.5)	1,954 (40.3)	0.051	27 (50.9)	2,194 (39.7)	0.10	36 (35)	144 (48.6)	2,041 (39.4)	0.004
Transfer to rehab center	11,539	622 (5.4)	123 (6.6)	499 (5.2)	0.01	38 (2.4)	584 (5.8)	< 0.001	2 (1.8)	620 (5.4)	0.07	26 (14.2)	31 (4.8)	564 (5.3)	< 0.001
Primary expected payers (uniform)	11,467				< 0.001			< 0.001			0.03				< 0.001
Medicare		4,396 (38.3)	682 (36.8)	3,714 (38.6)		606 (39.0)	3,790 (38.2)		50 (40.9)	4,346 (38.3)		93 (50.6)	245 (37.5)	4,058 (38.2)	
Medicaid		1,379 (12)	326 (17.6)	1,053 (11)		195 (12.5)	1,184 (11.9)		21 (16.7)	1,358 (12)		13 (7.2)	63 (9.6)	1,303 (12.3)	
Private insurance		4,946 (43.1)	708 (38.3)	4,237 (44.1)		604 (38.8)	4,342 (43.8)		51 (41.4)	4,895 (43.1)		75 (40.9)	296 (45.2)	4,575 (43)	
Self-pay/no charge/other		746 (6.5)	136 (7.3)	610 (6.3)		151 (9.7)	595 (6.0)		1 (1.1)	745 (6.6)		2 (1.1)	51 (7.8)	693 (6.5)	
Primary expected payers (uniform)	11,467				0.14			0.58			1.00				0.003
Not Medicare		7,071 (61.7)	1,170 (63.2)	5,901 (61.4)		949 (61.0)	6,122 (61.8)		73 (59.1)	6,998 (61.7)		91 (49.4)	409 (62.5)	6,571 (61.8)	
Medicare		4,396 (38.3)	682 (36.8)	3,714 (38.6)		606 (39.0)	3,790 (38.2)		50 (40.9)	4,346 (38.3)		93 (50.6)	245 (37.5)	4,058 (38.2)	
Index admission total charge ($1,000), median (IQR)	11,539	706.1 (0.4, 10,000)	706.1 (509.8, 1,170.8)	706.0 (456.3, 1,228.7)	0.07	609.0 (451.5, 906.1)	732.5 (470.5, 1,277.0)	< 0.001	663.0 (449.6, 1,204.1)	706.1 (465.3, 1,217.0)	0.12	467.5 (329.2, 763.7)	499.3 (359.0, 772.2)	724.1 (480.5, 1,256.2)	< 0.001
Length of stay (days), median (IQR)	11,539	25 (15, 47)	26 (16, 51)	25 (15, 47)	0.004	19 (12, 36)	26 (15, 49)	< 0.001	27 (12, 68)	25 (15, 47)	0.89	23 (13, 41)	22 (13, 51)	25 (15, 47)	0.004
Days from admission to procedure (heart txp), median (IQR)	11,539	1 (0, 20)	1 (1, 22)	1 (0, 20)	0.28	1 (0, 9)	1 (1, 21)	< 0.001	3 (1, 37)	1 (1, 20)	0.12	1 (0, 12)	1 (0, 21)	1 (1, 20)	0.004
Elixhauser comorbidity index, mean (± SD)	11,539	6.8 (± 2.0)	6.6 (± 1.9)	6.8 (± 2.1)	0.02	6.3 (± 2.3)	6.8 (± 2.0)	< 0.001	5.8 (± 2.0)	6.8 (± 2.0)	0.80	8.0 (± 1.9)	6.3 (± 2.1)	6.8 (± 2.0)	0.20
Graft rejection	11,539	1,720 (14.9)	256 (13.8)	1,464 (15.1)	0.28	248 (16)	1,472 (14.7)	0.45	13 (10.9)	1,707 (15)	0.30	35 (19.2)	80 (12.2)	1,605 (15)	0.16
Graft failure	11,539	436 (3.8)	83 (4.5)	353 (3.6)	0.17	46 (3)	390 (3.9)	0.29	8 (6.8)	428 (3.7)	0.14	4 (2)	14 (2.2)	418 (3.9)	0.16

Abbreviations: IQR, interquartile range; SD, standardized deviation; Txp, transplant.
Values are in frequency and % unless otherwise specified.

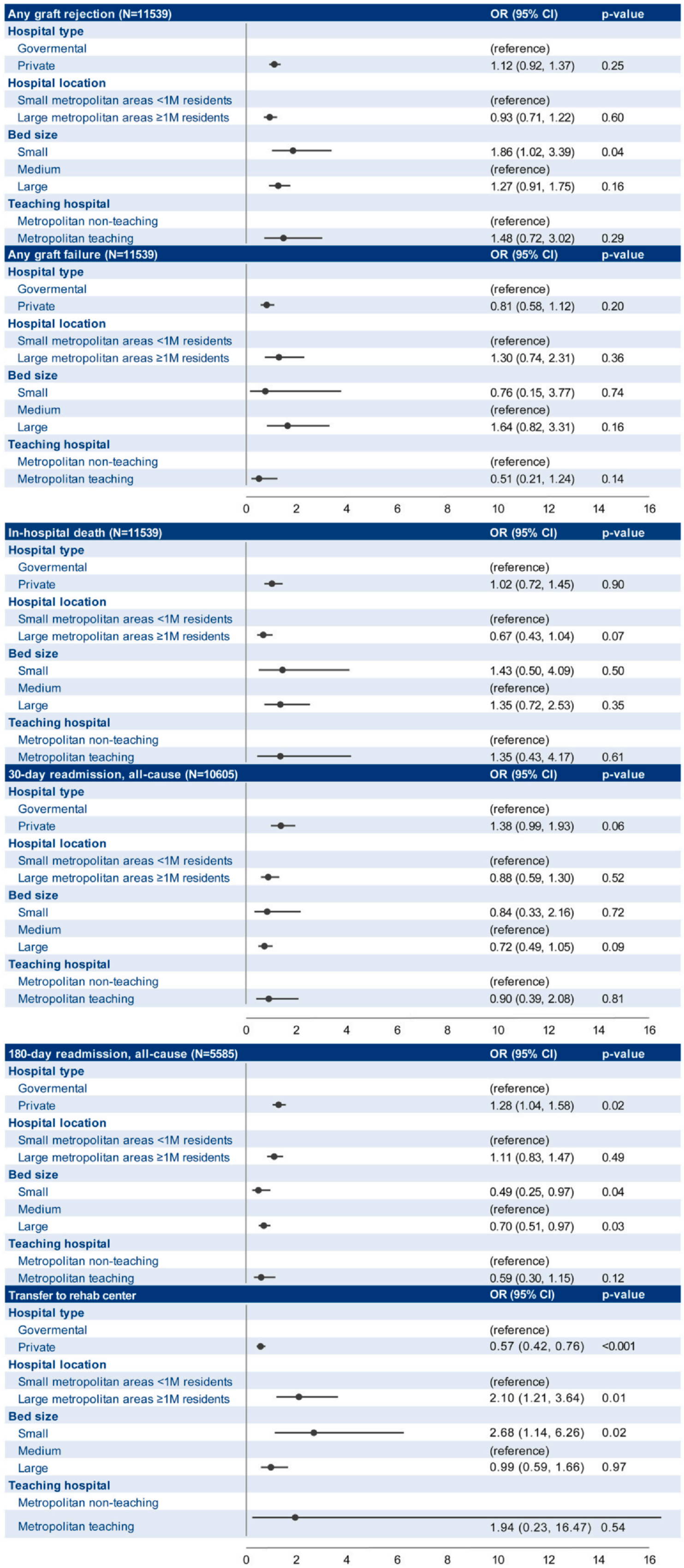

Figure 2 Multivariable regression model for in-hospital death, All-cause 30-day readmissions, all-cause 180-day readmissions, transfer to rehab center, graft rejection, and graft failure by hospital characteristics.

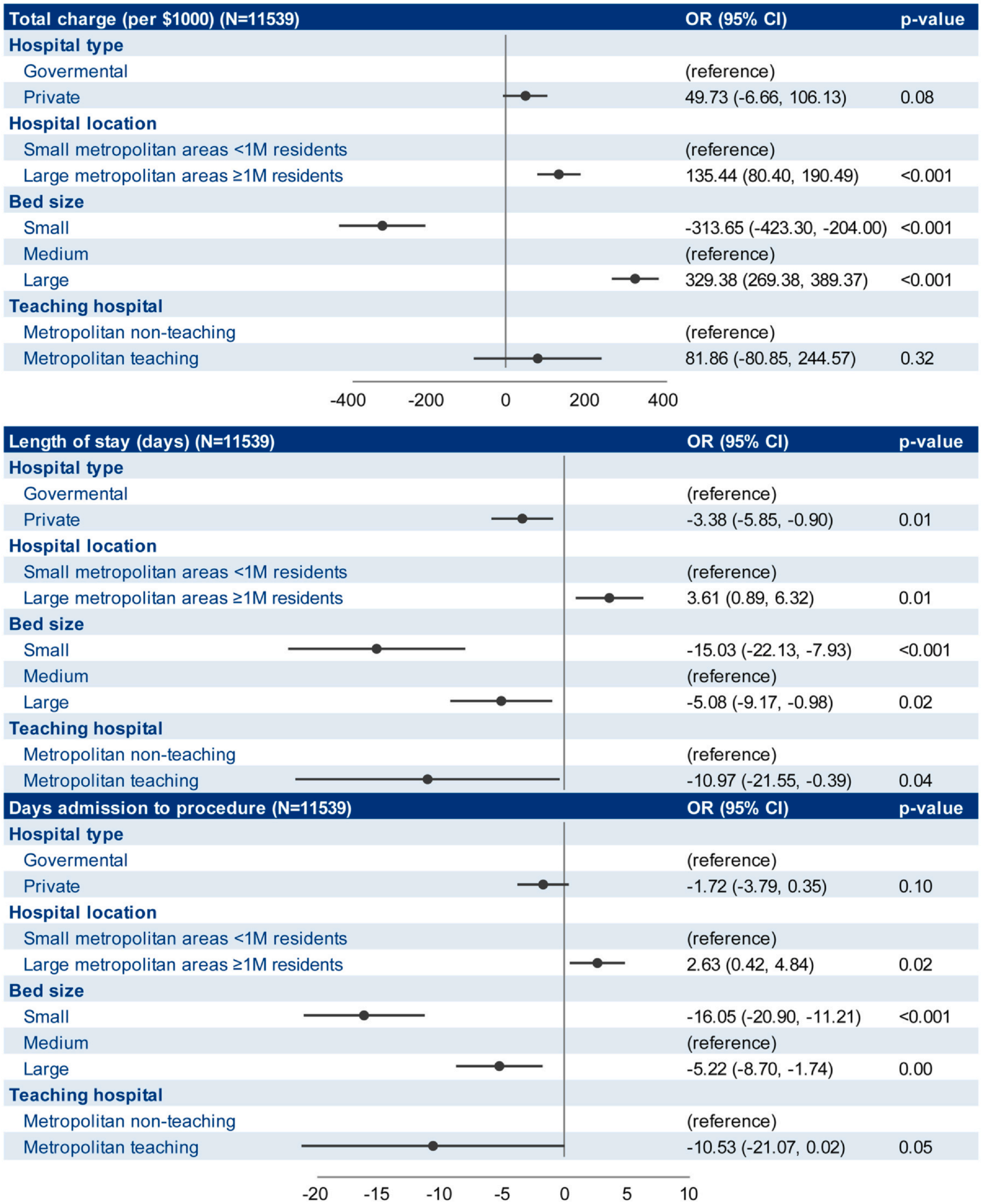

Figure 3 Multivariable generalized linear model for total charge, length of stay, and days of admission to procedure by hospital characteristics.

$706,100 in a large hospital compared to $467,500 and $499,300 in small and medium hospitals, respectively. No significant difference was seen in graft rejection and graft failure between the different size hospitals (Figure 2). Multivariable logistic regression analysis showed no association between hospital size and in-hospital mortality and 30-days all cause readmissions. However, there was a significant association between small hospital and graft rejection in the multivariable logistic regression model with patients having increased odds of rejection ((odds ratio) OR 1.86, 95% (confidence interval) CI 1.02-3.39, $p = 0.04$). In the univariable linear model, the cost of the cardiac transplantation index hospitalization was $377,200 more in reference to medium hospitals ($p < 0.001$). The multivariable model showed that small hospitals were associated with a lower cost (−313.65, 95% CI −423.30 to −204.00, $p < 0.001$), lower length of stay (−15.03, 95% CI −22.13 to −7.18, $p < 0.001$), and lower days of admission to procedure (−16.05, 95% CI −20.90 to −11.21, $p < 0.001$) (Figure 3) while having patients with higher Elixhauser comorbidity index (small hospital Index: 8.0; medium hospital index: 6.3; large hospital index: 6.8).

Hospital geographic location

Only 13.5% (1,555) of transplants were performed in hospitals in small metropolitan areas compared to 9,984 (86.5%) cardiac transplants performed in large metropolitan area hospitals. In-hospital mortality was higher in small metropolitan hospitals compared to large metropolitan hospitals (6.8% vs 5.1%, $p = 0.004$). Small metropolitan hospitals had higher 30-day readmission rate at 8.3% vs 6.6% in large metropolitan areas ($p = 0.03$). Transfer to rehab centers was higher in large metropolitan hospitals compared to small metropolitan hospitals (5.8% vs 2.4%, $p < 0.001$). The primary payer was Medicare for the majority of small metropolitan hospitals compared to most being private insurance in the large metropolitan hospitals. The cost of transplantation was higher in large metropolitan hospitals when compared to the small metropolitan area hospitals ($732,500 vs $609,000, $p < 0.001$). Length of stay was longer (26 days) in large metropolitan area hospitals compared to (19 days) the smaller area metropolitan hospitals ($p < 0.001$). Graft rejection and graft failure rates were similar. The univariable and multivariable logistic regression analyses did not show any association between hospital location and in-hospital death, 30-day readmission, 180-day readmission, graft rejection, and graft failure (Figure 2). Cardiac transplant was associated with higher cost, longer length of stay, and longer days from admission to transplant in large metropolitan hospitals when compared to hospitals in small metropolitan areas (Figure 3). The Elixhauser index of patients was 6.8 in large metropolitan area hospitals compared to 6.3 in hospitals in small metropolitan areas.

Hospital teaching status

Most of the transplants (11,416) were performed in teaching hospitals with only 1% (123) of transplants performed in nonteaching hospitals. There was no difference in any of the outcomes of interest by teaching status (Figures 2 and 3).

Implementation of MCS

The percentage of patients at the time of transplant who had a/an LVAD, IABP, ECMO, and percutaneous-ventricular assist device (p-VAD) was 24.4%, 19.8%, 3.8%, and 3.3%, respectively. Government-owned hospitals were significantly more likely to utilize ECMO and *p*-VAD; however, private hospitals use IABPs more frequently. Of note, we performed a subanalysis of implementation of MCS before and after the incorporation of the new allocation system (October 2018) (Table S6). This analysis showed a decrease in the use of LVAD (26.9% vs 18.8%, $p < 0.001$) and an increase in the use of ECMO (0.4% vs 11.8%, $p < 0.001$), p-VADs (1.8% vs 6.5%, $p < 0.001$), and IABPs (12.8% vs 35.8%, $p < 0.001$). Further trends in implementation of MCS by hospital characteristics can be seen in Table 1.

The multivariable logistic regression model showed patients on ECMO were more likely to die in hospital (OR: 6.67; CI: [4.03-11.05], $p < 0.001$). On the other hand, patients on IABP were less likely to get readmitted at 30 days (OR: 0.54; CI: [0.36-0.81], $p = 0.003$). There was a higher odds of graft failure in patient who received MCS with LVAD (OR: 1.73; CI [1.24-2.42], $p = 0.001$), ECMO (OR: 3.61; CI [2.11-6.17], $p < 0.001$), or IABP (OR: 1.76; CI [1.21-2.55], $p = 0.003$) when compared to no MCS (Figure 4).

Furthermore, generalized linear model showed a lower cost (−138.13; CI [−186.57 to −89.70], $p < 0.001$) and length of stay (−9.24; CI [−11.37 to −7.12], $p < 0.001$) in patients receiving a transplant with an LVAD. However, other MCS methods were associated with significantly higher cost and length of stay. Having an LVAD was associated with lower days of admission to procedure (−9.91; CI [−11.49 to −8.32], $p < 0.001$). However, use of a p-VAD or IABP was significantly associated with higher days of admission to procedure.

Discussion

In 2022 over 4,100 heart transplants were performed in the US, a 7.7% increase from 2021 and a gradual increase over the last decade.[11] Disparities related to patient characteristics have been described in relation to access and outcomes for heart transplant but there is limited understanding on outcome differences related to center characteristics.[12,13] There are now more government-owned, smaller, nonmetropolitan, and nonteaching centers that offer solid organ transplantation.[14,15] In this study, using a large publicly available dataset we analyzed outcomes after heart transplant by center characteristics: ownership, size, location, and teaching status. While higher procedural volumes are in general associated with better outcomes, Kilic et al found that volume accounts for only 16.7% to 18.2% of variability in 1- and 5-year mortality, respectively.[16,17] In our study, while our reference hospital characteristics (private, metropolitan, large, teaching) had more volume of patients in our cohort not all the results were in their favor. Small hospitals seem to maintain lower cost, lesser admission stay with a higher patient complexity. Hence, other structural factors beyond just the volume reflect the institutions' ability to provide complex care for these patients could be contributing to the quality outcomes.

Ownership has shown to impact postoperative complications in other cardiac surgeries, as the type of ownership typically impacts system operations, costs, financial management, and personnel issues.[18,19] Our study reveals that such an impact is not obvious for cardiac transplantation in the US as hospital ownership between government and private had no impact on mortality during the index admission for heart transplantation. On the same page, it is reassuring that other hospital characteristics studied (size, location, and teaching status) did not impact hospital mortality after heart transplantation. These results provide an

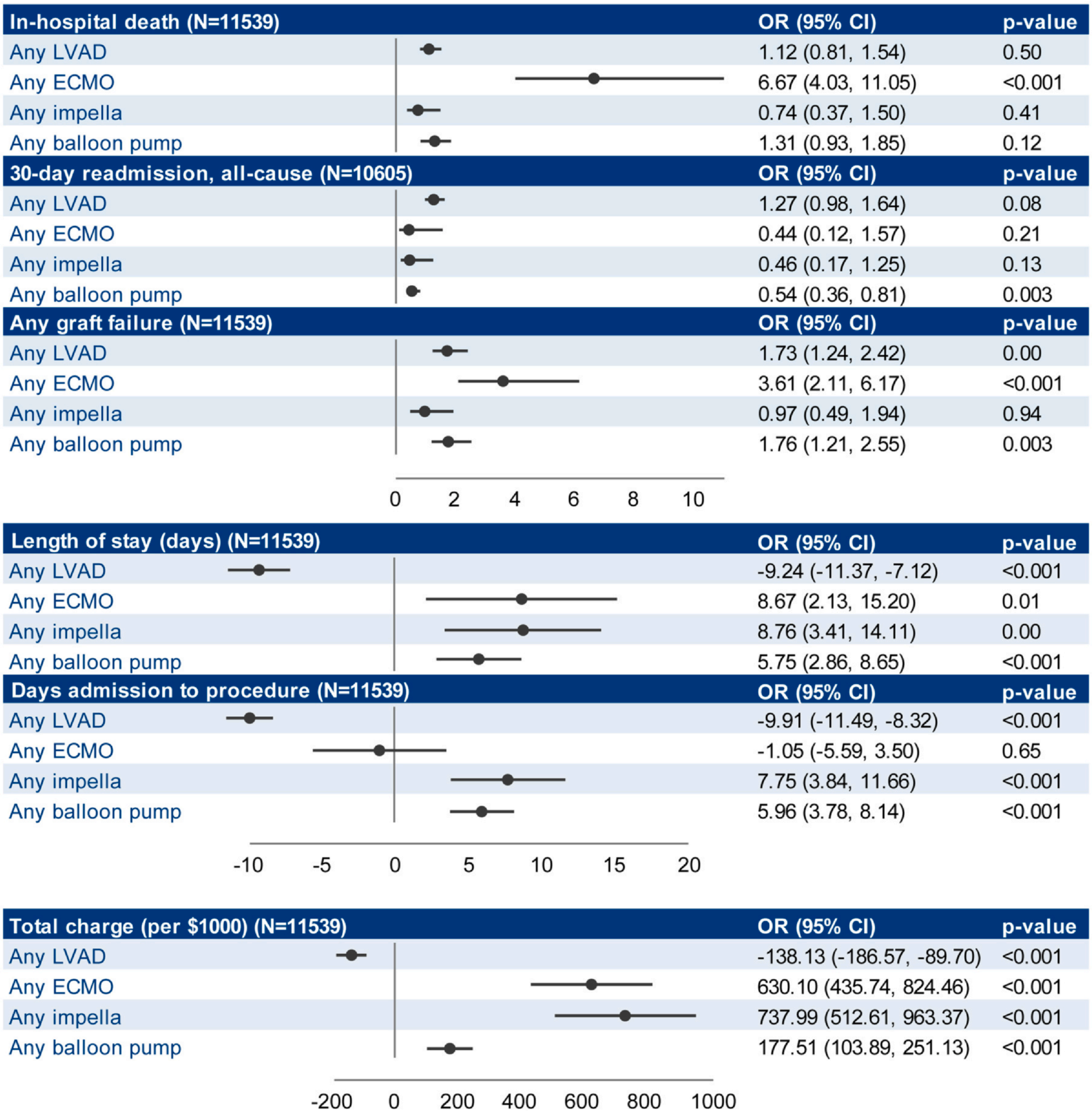

Figure 4 Multivariable regression model for in-hospital death, all-cause 30-day readmission, graft failure, total charge, length of stay, and days of admission to procedure by different cardiopulmonary support. ECMO, extracorporeal membrane oxygenation; LVAD, left ventricular assist device.

opportunity for heart transplantation to be embraced by various hospital types to further overcome the access to heart transplantation disparity. It is important to acknowledge that majority of transplants are being performed in private, large-sized hospitals located in large metropolitan areas reflecting lack of access to rural America.

Another quality metric that has gained importance to curb costs in the health care system is the hospital readmission rate. Hospital readmission rate is particularly important in the transplantation field, as readmissions have been associated with increased risk of mortality and graft failure in solid organ transplantation.[20] Thirty-day all-cause readmission rate was lower in the government hospitals when compared to privately owned hospitals. With rejection being identified as a top cause of 30-day readmission in cardiac transplantation, our results showed no difference in organ rejection by hospital ownership, location, and teaching status.[21] However, we did see an increased odds of rejection in smaller bed size hospitals. This could be due to volume and center resources as described in other solid organ transplantation, but more granular data are necessary to evaluate this association.[15] It is concerning to see an overall high 180-day readmission rate in all institutions. While transplant programs are held accountable for survival, there is no mandate to reduce readmission rates currently. While 30-day readmission is low, such a high readmission rate at 6 months does reflect a high burden of care of these patients and might need attention for quality improvement initiatives. The increasing cost of health care in US has been a concern and many studies have shown cost of care does not equate to better care.[22,23] Our study showed that the average heart transplant index admission cost from 2016-2019 was $706,100, and the cost increased from $584,100 in 2016 to $855,400 in 2019. This increase in cost was not associated with any change in patient comorbidities or in-hospital mortality. Even though more granular data are needed to identify the causes of this increase in cost, increase in MCS (ECMO, IABP, p-VAD) use and hospital length of stay, as shown in our data, could have contributed to this increase. Our data also showed that cost of transplant episode was lower for patients bridged to transplant with an LVAD compared to temporary MCS devices. The current allocation policy seems to have impacted the landscape of utilization of LVADs and temporary MCS devices and this cost implication has not been addressed. While we exert caution on not concluding that the strategy of bridging with an LVAD is less costly (because the data in this study do not factor the overall cost incurred to care for the LVAD patients from implant to transplant), the data highlight the fact that temporary MCS bridge to transplant does have cost implications and further studies are needed to provide guidance in overall cost effectiveness of temporary Mechanical Circulatory Support vs durable MCS strategy for bridging patients to heart transplant. Furthermore, the cost of transplantation was significantly less in nonmetropolitan areas compared to metropolitan and in smaller bed size hospitals compared to larger bed size hospitals. While this can potentially be justified by the general costs in metropolitan area being higher, further understanding might give insight into potential opportunities for lowering costs if certain practice patterns in smaller hospitals and nonmetro hospitals could lend to this lower cost.

Limitations

There are various limitations of this study, mainly, the retrospective and observational analysis using an administrative dataset. Hence, the findings in this study cannot establish causation. Yet, the large number of heart transplantations with the ability to assess hospital characteristics does render value. Secondly, there is a potential for measured and unmeasured confounding not gathered by this database that can influence the findings. Thirdly, follow-up information for these patients is not available which can influence the outcomes of interest. Given the provided patient linkage numbers and hospital identifiers cannot track the same patients/hospitals across years, NRD does not capture interstate hospitalization and does not link patients across years, which can impact readmission data as each year of data was considered as a separate sample year.[24] Furthermore, ICD codes from administrative data are prone to error which can impact our findings. Lastly, most of our data represent short-term transplant outcomes; therefore, long-term outcomes are essential to evaluate hospital characteristics.

Conclusion

While our study showed no significant difference in in-hospital mortality in multivariate, 30-day readmission, graft failure, or graft rejection by hospital ownership, location, or teaching status. These results show that cardiac transplantation models can be translated to different hospital characteristics with similar short-term outcomes; however, long-term data are necessary to evaluate patient outcomes[7].

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jhlto.2024.100085.

References

1. Akintoye E, Alvarez P, Shin D, et al. Changing demographics, temporal trends in waitlist, and posttransplant outcomes after heart transplantation in the United States: analysis of the UNOS database 1991-2019. Circ Heart Fail 2021;14:e008764. https://doi.org/10.1161/CIRCHEARTFAILURE.121.008764.
2. Parker WF, Chung K, Anderson AS, et al. Practice changes at U.S. transplant centers after the new adult heart allocation policy. J Am Coll Cardiol 2020;75:2906-16. https://doi.org/10.1016/j.jacc.2020.01.066.
3. Châtelet V, Gatault P, Hazzan M, et al. Transplant center characteristics associated with living-donor kidney transplantation: a cohort study with a hierarchical modeling approach. Transpl Int 2019;32:865-75. https://doi.org/10.1111/tri.13429.
4. Bloom JE, Nehme Z, Andrew E, et al. Hospital characteristics are associated with clinical outcomes in patients with cardiogenic shock. Shock 2022;58:204-10. https://doi.org/10.1097/SHK.0000000000001974.
5. Gad MM, Ahuja KR, Bazarbashi N, et al. The impact of hospital characteristics on the outcomes of interventional cardiac procedures. JACC Cardiovasc Interv 2019;12:1872-4. https://doi.org/10.1016/j.jcin.2019.05.033.
6. Cronin CE, Bolon DS. Comparing hospital mission statement content in a changing healthcare field. Hosp Top 2018;96:28-34. https://doi.org/10.1080/00185868.2017.1366188.
7. Briasoulis A, Inampudi C, Akintoye E, et al. Effect of hospital ownership on outcomes after left ventricular assist device implantation in the United States. Ann Thorac Surg 2019;107:527-32. https://doi.org/10.1016/j.athoracsur.2018.08.051.
8. NRD description of data elements. Available at: https://hcup-us.ahrq.gov/db/nation/nrd/nrddde.jsp, accessed March 1, 2024.
9. Statistical learning with sparsity: the Lasso and generalizations; 2015. Available at: https://play.google.com/store/books/details?id=f-A_CQAAQBAJ, accessed September 8, 2023.
10. Ho ATY, Huynh KP, Jacho-Chávez DT, Rojas-Baez D. Data science in Stata 16: Frames, lasso, and python integration. J Stat Softw 2021;98:1-8. https://doi.org/10.18637/jss.v098.s01.
11. United Network for Organ Sharing. UNOS; January 8, 2015. Available at: https://unos.org/, accessed September 10, 2023.
12. Hess NR, Seese LM, Sultan I, et al. Geographic disparities in heart transplantation persist under the new allocation policy. Clin Transplant 2021;35:e14459. https://doi.org/10.1111/ctr.14459.
13. Chouairi F, Fuery M, Clark KA, et al. Evaluation of racial and ethnic disparities in cardiac transplantation. J Am Heart Assoc 2021;10:e021067. https://doi.org/10.1161/JAHA.120.021067.
14. Gunnar W. The VA transplant program: a rebuttal to criticism and a look to the future. Am J Transplant 2019;19:1288-95. https://doi.org/10.1111/ajt.15295.
15. Alqahtani SA, Stepanova M, Kabbara KW, et al. Liver transplant center size and the impact on clinical outcomes and resource utilization. Transplantation 2022;106:988-96. https://doi.org/10.1097/TP.0000000000003915.
16. Grimm JC, Kilic A, Shah AS, et al. The influence of institutional volume on the incidence of complications and their effect on mortality after heart transplantation. J Heart Lung Transplant 2015;34:1390-7. https://doi.org/10.1016/j.healun.2015.05.014.

17. Kilic A, Weiss ES, Yuh DD, et al. Institutional factors beyond procedural volume significantly impact center variability in outcomes after orthotopic heart transplantation. Ann Surg 2012;256:616-23. https://doi.org/10.1097/SLA.0b013e31826b4bc9.
18. Atala R, Kroth PJ. The association between hospital ownership and postoperative complications: does it matter who owns the hospital? Health Informatics J 2020;26:2193-201. https://doi.org/10.1177/1460458219899827.
19. Baker CM, Messmer PL, Gyurko CC, et al. Hospital ownership, performance, and outcomes: assessing the state-of-the-science. J Nurs Adm 2000;30:227-40. https://doi.org/10.1097/00005110-200005000-00004.
20. Li AHT, Lam NN, Naylor KL, et al. Early hospital readmissions after transplantation: burden, causes, and consequences. Transplantation 2016;100:713-8. https://doi.org/10.1097/TP.0000000000000917.
21. Alvarez PA, Briasoulis A, Malik AH. Trends, risk factors, and mortality of unplanned 30-day readmission after heart transplantation. Am J Cardiol 2021;154:130-3. https://doi.org/10.1016/j.amjcard.2021.06.002.
22. Tsugawa Y, Jha AK, Newhouse JP, et al. Variation in physician spending and association with patient outcomes. JAMA Intern Med 2017;177:675-82. https://doi.org/10.1001/jamainternmed.2017.0059.
23. Papanicolas I, Woskie LR, Jha AK. Health care spending in the United States and other high-income countries. JAMA 2018;319:1024-39. https://doi.org/10.1001/jama.2018.1150.
24 Limitations on using the nationwide readmissions database (NRD) consider each year of the NRD as a separate sample. Available at: https://hcup-us.ahrq.gov/db/nation/nrd/limitationsonusingthenrd.pdf, accessed September 10, 2023.