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THE SOCIETY OF THORACIC SURGEONS INTERMACS ANNUAL REPORT

The Society of Thoracic Surgeons Intermacs 2020 Annual Report

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The Society of Thoracic Surgeons (STS)-Interagency Registry for Mechanically Assisted Circulatory Support (Intermacs) 2020 Annual Report reviews outcomes on 25,551 patients undergoing primary isolated continuous-flow left ventricular assist device (LVAD) implantation between 2010 and 2019. In 2019, 3198 primary LVADs were implanted, which is the highest annual volume in Intermacs history. Compared with the previous era (2010-2014), patients who received an LVAD in the most recent era (2015-2019) were more likely to be African American (26.8% vs 22.9%, $P < .0001$) and more likely to be bridged to durable LVAD with temporary mechanical support devices (36.8% vs 26.0%, $P < .0001$). In 2019, 50% of patients were INTERMACS Profile 1 or 2 before durable LVAD, and 73% received an LVAD as destination therapy. Magnetic levitation technology has become the predominant design, accounting for 77% of devices in 2019. The 1- and 2-year survival in the most recent era has improved compared with 2010 to 2014 (82.3% and 73.1% vs 80.5% and 69.1%, respectively; $P < .0001$). Major bleeding and infection continue to be the leading adverse events. Incident stroke has declined in the current era to 12.7% at 1 year. STS-Intermacs research publications are highlighted, and the new quality initiatives are introduced.

(Ann Thorac Surg 2021;111:778-92)

The Interagency Registry for Mechanically Assisted Circulatory Support (Intermacs) database was a National Heart, Lung, and Blood Institute-sponsored initiative established in 2005 and managed at the University of Alabama at Birmingham. Since its inception as a partnership enterprise between physicians, industry partners, the National Heart, Lung and Blood Institute, the United States (US) Food and Drug Administration (FDA), and the Centers for Medicare and Medicaid Services, the Registry had the fundamental objective of advancing the understanding and application of mechanical circulatory support (MCS) to improve the duration and

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The Supplemental Figures can be viewed in the online version of this article [https://doi.org/10.1016/j.athoracsur.2020.12.038] on http://www.annalsthoracicsurgery.org.

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Abbreviations and Acronyms

BiVAD = biventricular assist device
BTC = bridge to candidacy
BTT = bridge to transplant
CF = continuous flow
CI = confidence interval
DT = destination therapy
FDA = Food and Drug Administration
HVAD = HeartWare Ventricular Assist Device
INTERMACS = Interagency Registry for Mechanically Assisted Circulatory Support
LVAD = left ventricular assist device
MCS = mechanical circulatory support
RVAD = right ventricular assist device
STS = The Society of Thoracic Surgeons
TAH = total artificial heart
US = United States

quality of life for individuals with advanced heart failure.

In December 2017, Intermacs accomplished its initial research mission and started a new chapter with The Society of Thoracic Surgeons (STS) National Database. As a fourth component of the STS National Database, the STS-Intermacs Database joined the Cardiac Surgery Database, General Thoracic Surgery Database, and Congenital Heart Surgery Database on January 1, 2018. The primary goals of this new Intermacs era are to (1) continue reporting the longitudinal clinical outcomes of patients who receive FDA-approved durable MCS devices in the US, (2) develop benchmarks to guide future clinical study toward the goals of reducing adverse events and improving quality of life on long-term MCS support, and (3) to provide contemporary and relevant quality metrics that centers can use for quality assessment and performance improvement. With 184 active reporting sites and more than 31,000 patients enrolled since June 2006, the Registry represents the only reporting platform for LVAD outcomes in North America and is a fundamental instrument for the advancement of the MCS field. Intermacs represents real-world outcomes devoid of clinical trial inclusion and exclusion criteria at transplant and nontransplant centers across the US with varying center volumes and patient demographics.

Since the creation of the Intermacs database in 2005, the STS-Intermacs Annual Report has been established as an essential instrument for the analysis and publication of the continuous progress in the treatment of heart failure patients with MCS devices. Previous Annual Reports have described the transformational changes that have occurred in the MCS field, including improved clinical outcomes determined by remarkable changes in LVAD technology and a significant growth in the clinical use of this lifesaving therapy. The most recent report has documented the shifting landscape of devices and indications, including the current predominance of centrifugal-flow technology and a shift toward destination therapy (DT) as the main indication for device implantation.[1] As LVAD technology evolves and clinical outcomes continue to improve, the focus of attention is now centered on longer-term survival free of adverse events and rehospitalizations.

The format of the STS-Intermacs report herein has changed. The goal of the new, more reproducible Annual Report format is to provide the MCS community (physicians, patients, researchers, governmental agencies, including the US FDA, Centers for Medicare and Medicaid Services, and the Joint Commission) with valuable general information from the STS-Intermacs Registry that is important for longitudinal patient care. The new Annual Report will be consistent with the other STS Databases and will highlight prior research from the STS Research Center and STS-Intermacs Database in the MCS field. To support the aims of the Intermacs Task Force to develop quality metrics and critical areas for research, the Annual Report will be followed every year by an Annual STS-Intermacs Special Task Force Report. A similar reporting format will be created for the PediMACS (pediatric portion of Intermacs) Database.

PATIENTS AND METHODS

The 2020 STS-Intermacs Annual Report includes all adult (aged ≥19 years) patients who underwent implantation of an FDA-approved durable MCS device from January 1, 2010, to December 31, 2019, with follow-up through June 30, 2020. Data analyses were subsequently focused on those patients who received an isolated primary continuous-flow (CF) LVAD. Thus, individuals on total artificial heart (TAH) support, isolated right ventricular assist device (RVAD) support, or those receiving biventricular assist device (BiVAD) support within the index LVAD operation were excluded from subsequent analytics. Preimplant patient characteristics and demographics, perioperative details, and adverse events during isolated CF LVAD support are reported for patients enrolled into Intermacs during the last 10 years. For all adverse events, Intermacs definitions from version 4.0 were used. Two different eras were analyzed: 2010-2014 and 2015-2019. Reporting of adverse events, rehospitalizations, and causes of death were limited to the last 5 years (January 2015 to December 2019). Events were categorized as early (0-90 days) and late (>90 days postoperative).

STATISTICAL ANALYSIS. For descriptive purposes, categorical variables are expressed as frequencies and percentages. Continuous variables are expressed as means ± SD. Categorical variables were compared with χ^2 testing and continuous variables were compared with

the t-test. Kaplan-Meier survival estimates were calculated, censoring patients at the time of transplantation or explant for recovery. Patients undergoing a device exchange were not censored in the analysis. For all survival analyses, differences for specific subsets of data were compared with the use of log-rank testing. Median survival times are quoted in months. Outcomes associated with specified strategies at the time of implant, including bridge to transplant (BTT), bridge to candidacy (BTC), and DT, were examined using the competing outcomes analysis by Fine and Gray, in which multiple mutually exclusive outcomes are tracked over time. At any point in time, the sum of the proportion (percentage) of patients in each outcome category equals 100%. Adverse events were calculated as event count, event rate (per patient-year), patient count, and patient percentage. Statistical analysis was quantified with SAS 9.4 software (SAS Institute, Inc, Cary, NC).

ETHICAL APPROVAL. The analyses reported here were approved by the Intermacs/PediMACS Committee of the STS Access & Publications Task Force under the Workforce on Research Development. Patient consent for STS-Intermacs data collection was obtained at enrolling centers according to local Institutional Review Board requirements.

RESULTS

INTERMACS MCS IMPLANT VOLUMES OVER TIME FOR ALL DEVICES. From January 2010 to December 2019, 27,298 adult patients received an FDA-approved durable MCS device with STS-Intermacs registration. The distribution of patients by device type is shown in Figure 1A. For the reported 10-year period, 28 patients (0.1%) received an isolated RVAD, 449 (1.6%) underwent a TAH implant, 217 (0.8%) received a pulsatile-flow durable LVAD or pulsatile BiVAD, and 26,604 (97.5%) underwent implantation of a durable CF LVAD or CF BiVAD support during the index LVAD operation. Of those on CF LVAD support, 25,551 (96%) were on isolated LVAD support, and 1053 (4%) had both RVAD and LVAD support implanted during the same operative procedure.

Implant volumes for all MCS devices over the last 10 years are shown in Supplemental Figure 1. TAH, isolated RVAD, and simultaneous BiVAD implant volumes remain largely unchanged. The yearly frequency of isolated LVAD implants according to device flow type is shown in Supplemental Figure 2. As noted in prior reports, there was a temporary decline in the total number of CF LVADs implanted in 2016 and 2017, but implant volumes increased in 2018 and 2019. Furthermore, a record number of 3198 primary CF LVADs were implanted in 2019. FDA approval of the HeartMate 3 (Abbott Labs, Chicago, IL) for BTT (August 2017) and for DT indication (October 2018), and approval of the HeartWare Ventricular Assist Device (HVAD; Medtronic, Inc, Minneapolis, MN) for DT indication (September 2017) likely affected durable LVAD implant volumes (Figure 1B).

Updated outcomes for BiVAD and TAH implants are reported in Supplemental Figures 3 to 6. Patients with biventricular failure continue to display high mortality, with 2-year survivals of 49% for patients on BiVAD CF support and 40% for those on TAH support. Detailed analyses of these patient subgroups have been reported previously.[2,3]

The focus of the remaining document will be on the 25,551 patients who received an FDA-approved isolated primary CF LVAD from January 2010 to December 2019.

ISOLATED CF LVAD COHORT CHARACTERISTICS. The baseline characteristics for patients on primary isolated CF LVAD support are summarized in Table 1. When analyzed according to era, LVAD recipients from 2015-2019 were more likely to be African American, more likely to have severe diabetes, but less likely to have had prior cardiac surgery or an implantable cardioverter defibrillator before LVAD implant, compared with the earlier era.

The other notable trend was the higher proportion of patients with signs of clinical instability. More patients were treated with temporary MCS before durable LVAD implant in the recent era vs the earlier era (36.8% vs 26.0%; $P < .001$), including extracorporeal membrane oxygenation support (5.9% vs 2.3%; $P < .001$) and an intraaortic balloon pump (26.2% vs 17.5%; $P < .001$). Although some statistically significant differences were noted in preimplant laboratory, echocardiographic, and hemodynamic data between the 2 cohorts, few were clinically meaningful.

TRENDS IN INTERMACS PROFILES, LVAD INDICATIONS, AND DEVICE FLOW TYPE. The INTERMACS Profile at the time of implantation, stratified according to era, is listed in Table 1. Half of the patients were Profile 1 or 2, and device implantation for patients who were INTERMACS Profiles 4 to 7 were less common in the more recent era (12.4% vs 18.6%). The patient profile by implant year for isolated primary CF LVAD is shown in Figure 2A.

Of the 25,551 CF primary LVAD implants from January 2010 to December 2019, 5607 (21.9%) were implanted as a BTT (listed), 6874 (26.9%) were for BTC, 12,865 (50.4%) were for DT, and 205 (0.8%) were for an indication listed as "other" (Table 1). The revised US heart allocation system that went into effect in October 2018 has likely contributed significantly to the changes noted in durable LVAD implant strategy over time. Before 2018, approximately 50% of patients received an LVAD for DT, while approximately 25% received a pump for BTT and another 25% for BTC. However, after implementation of

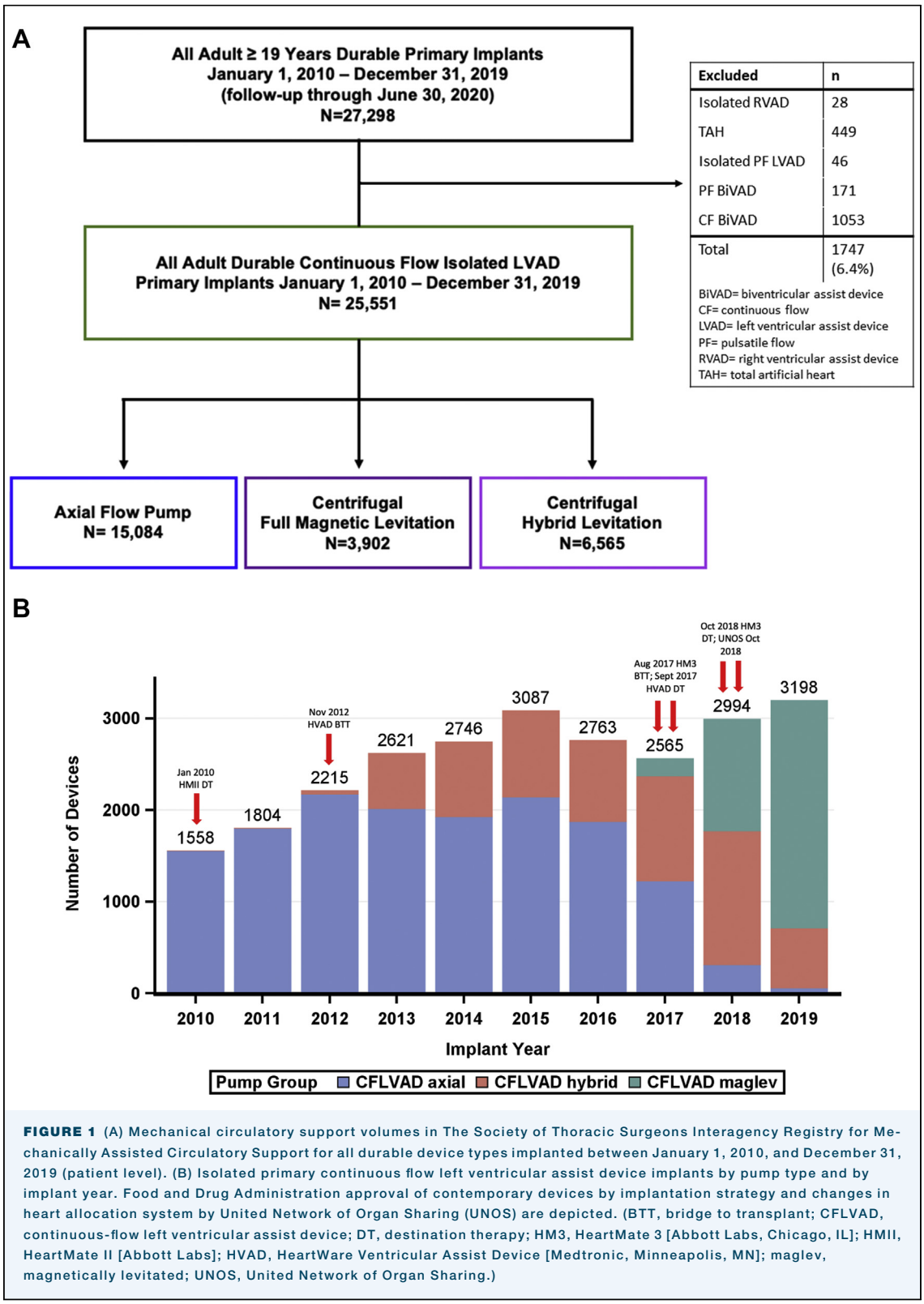

FIGURE 1 (A) Mechanical circulatory support volumes in The Society of Thoracic Surgeons Interagency Registry for Mechanically Assisted Circulatory Support for all durable device types implanted between January 1, 2010, and December 31, 2019 (patient level). (B) Isolated primary continuous flow left ventricular assist device implants by pump type and by implant year. Food and Drug Administration approval of contemporary devices by implantation strategy and changes in heart allocation system by United Network of Organ Sharing (UNOS) are depicted. (BTT, bridge to transplant; CFLVAD, continuous-flow left ventricular assist device; DT, destination therapy; HM3, HeartMate 3 [Abbott Labs, Chicago, IL]; HMII, HeartMate II [Abbott Labs]; HVAD, HeartWare Ventricular Assist Device [Medtronic, Minneapolis, MN]; maglev, magnetically levitated; UNOS, United Network of Organ Sharing.)

the new heart allocation system, more than 70% of LVADs were implanted as DT, and a minority were used as BTT or BTC (Figure 2B).

A dramatic shift occurred from 2010 to 2019 in the type of CF LVAD implanted. Axial-flow devices were the predominant device type implanted during 2010-2014.

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TABLE 1 Baseline Characteristics of Patients on Isolated Left Ventricular Assist Device Support

Patient Characteristics	All Patients (N = 25,551)	2010-2014 Era (n = 10,944)	2015-2019 Era (n = 14,607)	*P* Value[a]
Demographics				
Age at implant, y	57.1 ± 13.0	57.3 ± 12.9	57.0 ± 13.0	.06
Female sex	5496 (21.5)	2338 (21.4)	3158 (21.6)	.003
Race				<.0001
White	16,753 (65.6)	7540 (68.9)	9213 (63.1)	
Black	6417 (25.1)	2505 (22.9)	3912 (26.8)	
Other	2381 (9.3)	899 (8.2)	1482 (10.1)	
Body mass index, kg/m^2	28.7 ± 7.2	28.7 ± 6.7	28.6 ± 7.5	.4
Medical history				
Severe diabetes	2215 (8.8)	828 (7.8)	1387 (9.5)	<.0001
Dialysis	686 (2.7)	268 (2.4)	418 (2.9)	.04
Current ICD	19,989 (78.7)	8884 (81.7)	11,105 (76.5)	<.0001
History of cardiac surgery	8281 (32.4)	3907 (35.7)	4374 (29.9)	<.0001
Current smoker	1455 (5.8)	569 (5.4)	886 (6.1)	.02
Indication				
Device strategy				<.0001
Bridge to transplant—listed	5607 (21.9)	2647 (24.2)	2960 (20.3)	
Bridge to candidacy	6874 (26.9)	3559 (32.5)	3315 (22.7)	
Destination therapy	12,865 (50.4)	4669 (42.7)	8196 (56.1)	
Other	205 (0.8)	69 (0.6)	136 (0.9)	
Severity of illness				
Patient Profile				<.0001
1. Critical cardiogenic shock	4205 (16.5)	1581 (14.5)	2624 (18.0)	
2. Progressive decline	8964 (35.2)	3990 (36.6)	4974 (34.1)	
3. Stable but inotrope dependent	8474 (33.3)	3294 (30.2)	5180 (35.5)	
4-7. Resting symptoms, no inotropes	3829 (15.0)	2027 (18.6)	1802 (12.4)	
Inotropes	20,989 (82.5)	8723 (80.0)	12,266 (84.3)	<.0001
Ventilator support	1434 (5.6)	485 (4.4)	949 (6.5)	<.0001
Temporary circulatory support	6826 (32.4)	2219 (26.0)	4607 (36.8)	<.0001
ECMO	1123 (4.4)	255 (2.3)	868 (5.9)	<.0001
Intraaortic balloon pump	5739 (22.5)	1913 (17.5)	3826 (26.2)	<.0001
Primary heart failure etiology				<.0001
Ischemic cardiomyopathy	9908 (38.8)	4486 (41.0)	5422 (37.1)	
Nonischemic cardiomyopathy	13,055 (51.1)	5312 (48.5)	7743 (53.0)	
Other	2588 (10.1)	1146 (10.5)	1442 (9.9)	
Laboratory values				
Albumin, g/L	34.1 ± 6.4	34.0 ± 6.7	34.1 ± 6.1	.08
Blood urea nitrogen, mg/dL	29.2 ± 17.5	29.5 ± 18.2	29.0 ± 16.9	.04
Creatinine, mg/dL	1.4 ± 0.7	1.4 ± 0.7	1.4 ± 0.7	.09
International normalized ratio	1.3 ± 0.5	1.3 ± 0.6	1.3 ± 0.5	<.0001
Platelets, ×10/μL	196.0 ± 80.2	196.3 ± 80.0	195.7 ± 80.3	.6
Alanine aminotransferase, U/L	62.4 ± 193.3	69.8 ± 236.8	57.1 ± 154.5	<.0001
Aspartate transaminase, U/L	53.0 ± 186.2	57.9 ± 217.3	49.5 ± 160.1	.0005
Total bilirubin, mg/dL	1.4 ± 1.8	1.4 ± 1.8	1.3 ± 1.7	.1
Echocardiography				
LVEDD, cm	6.8 ± 1.1	6.8 ± 1.1	6.8 ± 1.1	.03
RV function: severe dysfunction	2807 (15.2)	1070 (16.6)	1737 (14.4)	<.0001
Severe regurgitation				
Aortic	131 (0.6)	50 (0.6)	81 (0.6)	.4
Mitral	5472 (23.5)	2270 (23.4)	3202 (23.6)	.8
Tricuspid	2709 (11.7)	1133 (11.8)	1576 (11.7)	.8
Hemodynamics				
Systolic blood pressure, mm Hg	105.7 ± 16.2	104.6 ± 16.1	106.5 ± 16.3	<.0001
Right atrial pressure, mm Hg	12.9 ± 8.3	13.5 ± 8.5	12.5 ± 8.2	<.0001

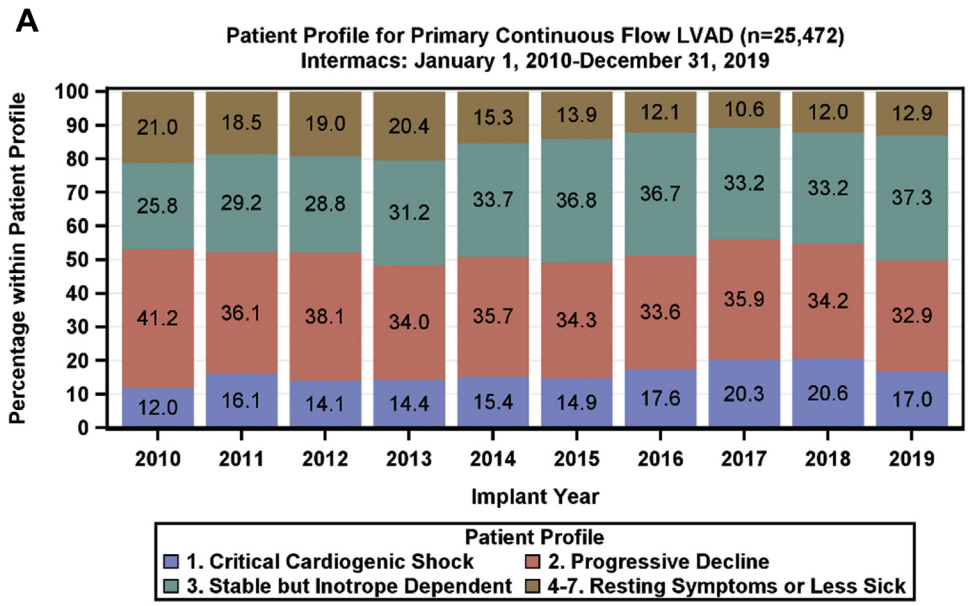
(*Continued*)

TABLE 1 Continued

Patient Characteristics	All Patients (N = 25,551)	2010-2014 Era (n = 10,944)	2015-2019 Era (n = 14,607)	*P* Value[a]
Pulmonary artery				
Systolic pressure, mm Hg	49.8 ± 14.9	50.1 ± 14.7	49.6 ± 15.0	.009
Wedge pressure, mm Hg	24.8 ± 9.3	24.5 ± 8.9	25.0 ± 9.5	<.0001
Cardiac index, L/min/m^2	2.2 ± 0.9	2.3 ± 1.0	2.2 ± 0.8	<.0001

[a]*P* value is comparing across eras.

Continuous data are reported as the mean ± SD and categorical data as n (%) of patients. ECMO, extracorporeal membrane oxygenator; ICD, implantable cardioverter defibrillator; LVEDD, left ventricular end diastolic dimension; RV, right ventricular.



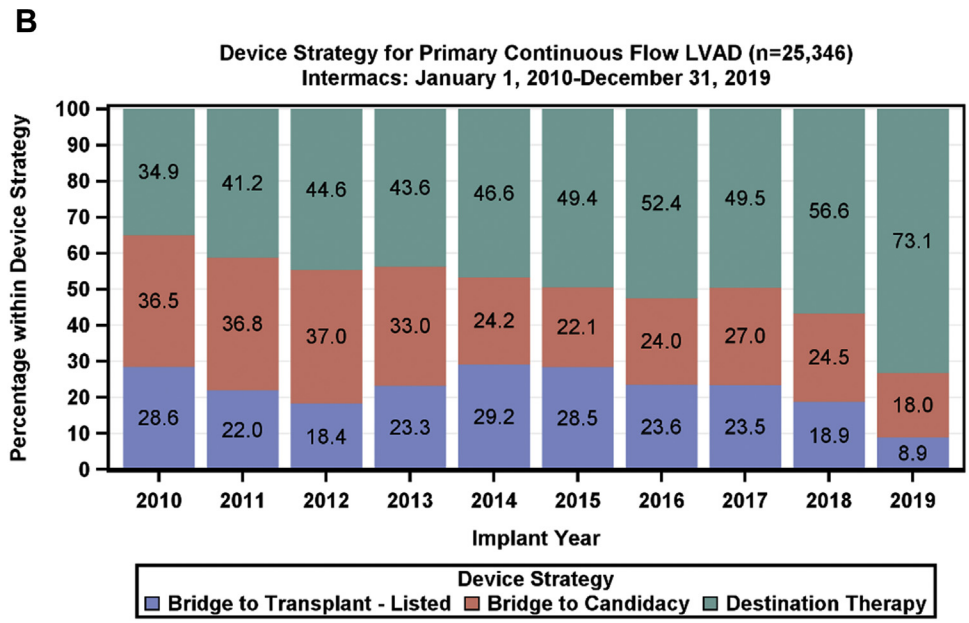


FIGURE 2 (A) Patient profile by implant year for primary continuous flow left ventricular assist devices (LVADs) (does not include 79 continuous LVAD patients with missing patient profile) and (B) implant strategy by implant year for primary continuous-flow LVADs (does not show "other," which contains 205 patients). (Intermacs, Interagency Registry for Mechanically Assisted Circulatory Support.)

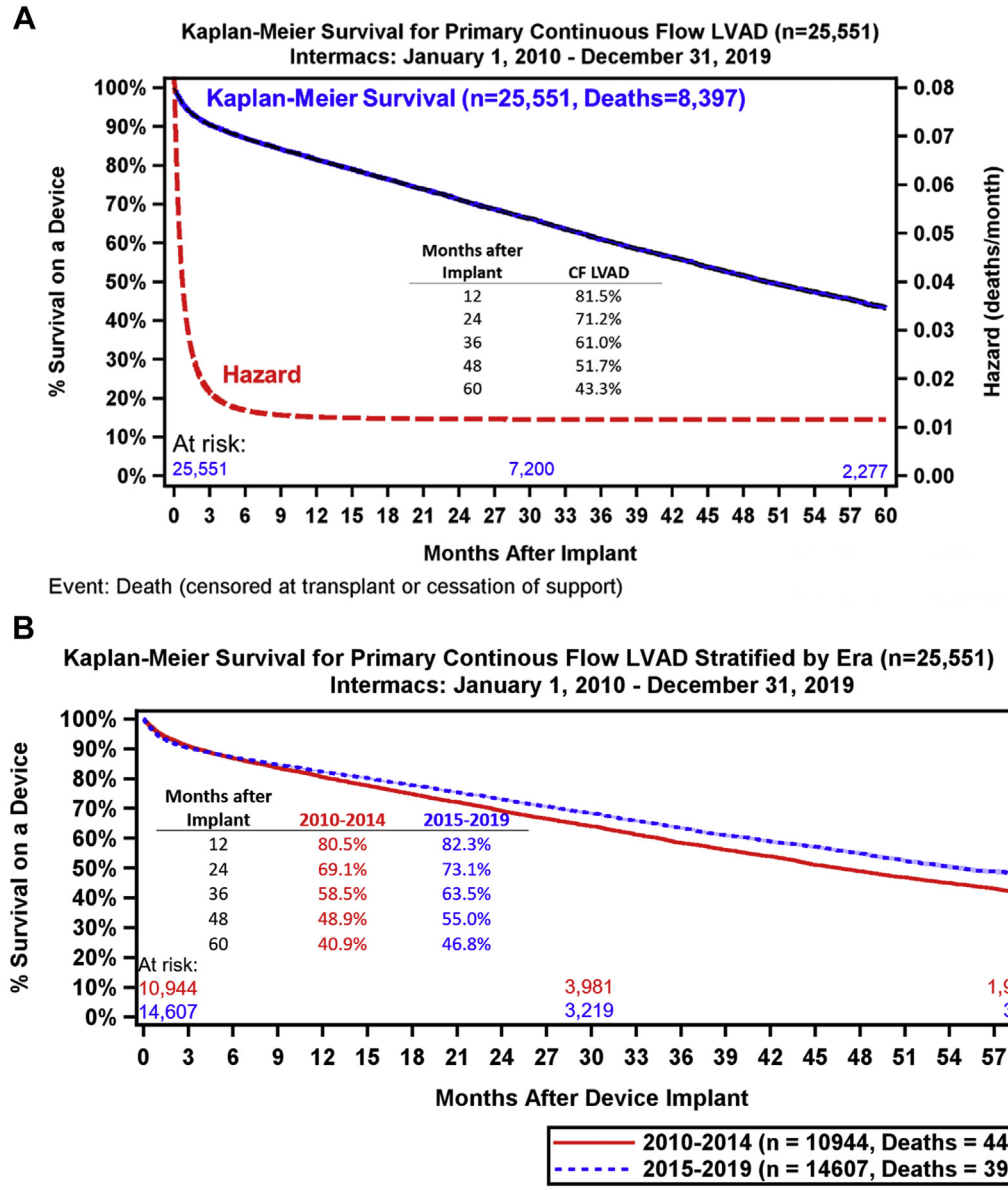


FIGURE 3 Kaplan-Meier survival curves for primary continuous-flow left ventricular assist devices (CF LVAD) (A) for the entire reporting period (with hazard shown in red) and (B) by era. (Intermacs, Interagency Registry for Mechanically Assisted Circulatory Support.)

However, the use of axial-flow devices declined after 2015 in favor of hybrid-levitation centrifugal-flow pumps. From 2017 to 2019, however, devices with full magnetic levitation have been increasingly used (Figure 1B). In 2019, CF devices with full magnetic levitation represented 77.7% of CF LVAD implants, CF flow devices with hybrid levitation represented 20.5% of implants, and CF devices with an axial design represented only 1.8% of implants.

SURVIVAL OUTCOMES FOR PATIENTS ON ISOLATED LVAD SUPPORT. The advent and evolution of CF LVAD technologies along with improvements in patient selection and clinical management have afforded improvements in clinical outcomes and patient survival. Overall survival during the past decade after CF LVAD implant is shown in Figure 3A. Despite increasing patient acuity and a higher proportion of patients undergoing the

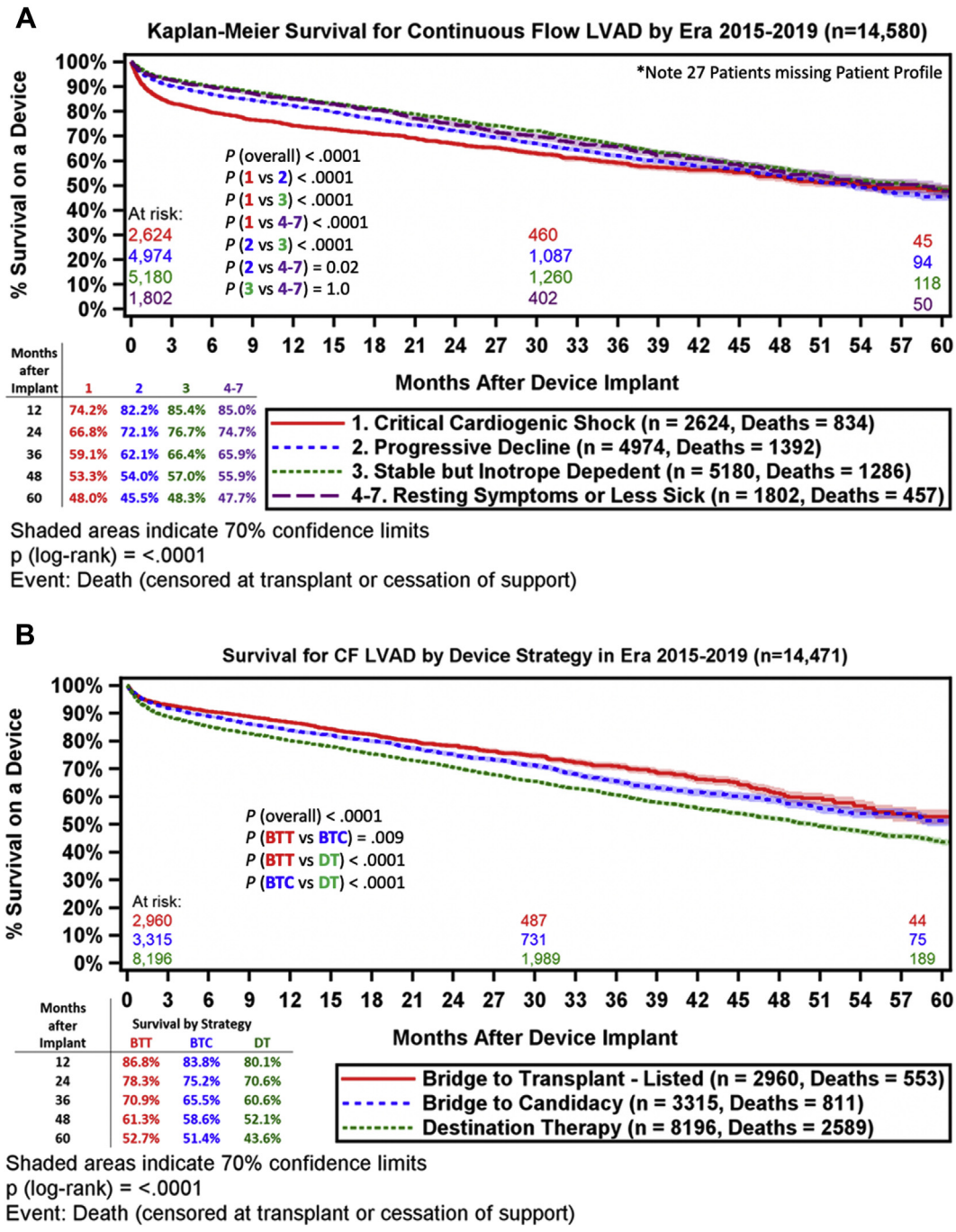


FIGURE 4 Kaplan-Meier survival curves for primary continuous-flow left ventricular assist devices (CF LVAD) for the 2015-2019 era (A) by patient profile and (B) by implant strategy. (BTC, bridge to candidacy; BTT, bridge to transplant; CF LVAD, continuous flow left ventricular assist device; DT, destination therapy.)

implant as DT, the 1- and 2-year survivals of patients undergoing implant between 2015 and 2019 are higher (82.3% [70% CI: 81.9%, 82.6%] and 73.1% [70% CI: 72.6%, 73.5%], respectively) than those (80.5% [70% CI: 80.1%, 80.9%] and 69.1% [70% CI: 68.8%, 69.6%]) of patients undergoing the implant between 2010 and 2014 (Figure 3B). The highest hazard of death remains in the early postoperative period and reaches a steady state thereafter. The median patient survival has increased from 46.5 months (95% CI: 44.7%, 48.2%

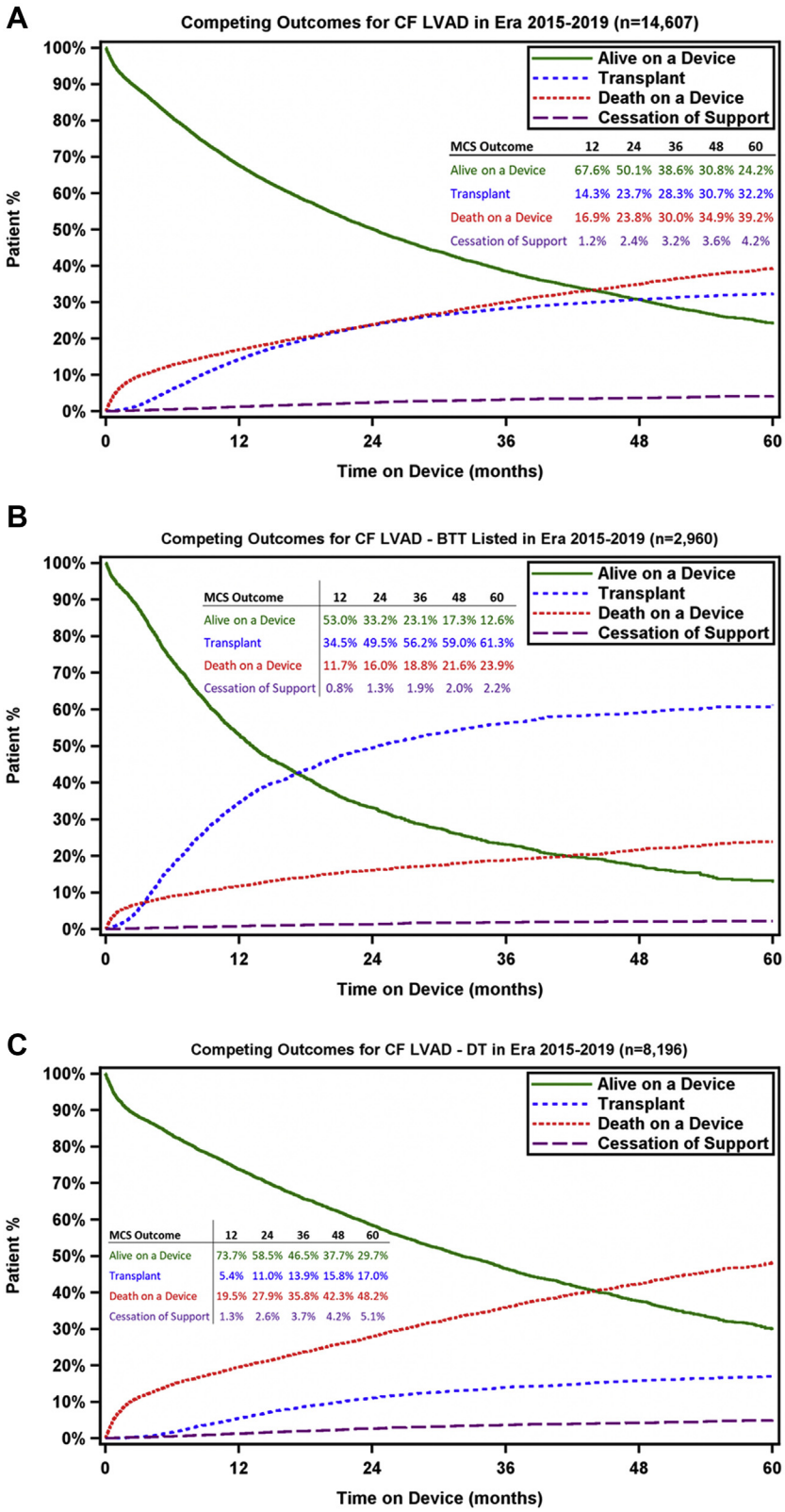


FIGURE 5 Competing outcomes depiction for isolated primary continuous-flow left ventricular assist device (CV LVAD) implants for the 2015-2019 era for (A) all implants, (B) bridge to transplant (BTT) implants, and (C) destination therapy (DT) implants. (MCS, mechanical circulatory support.)

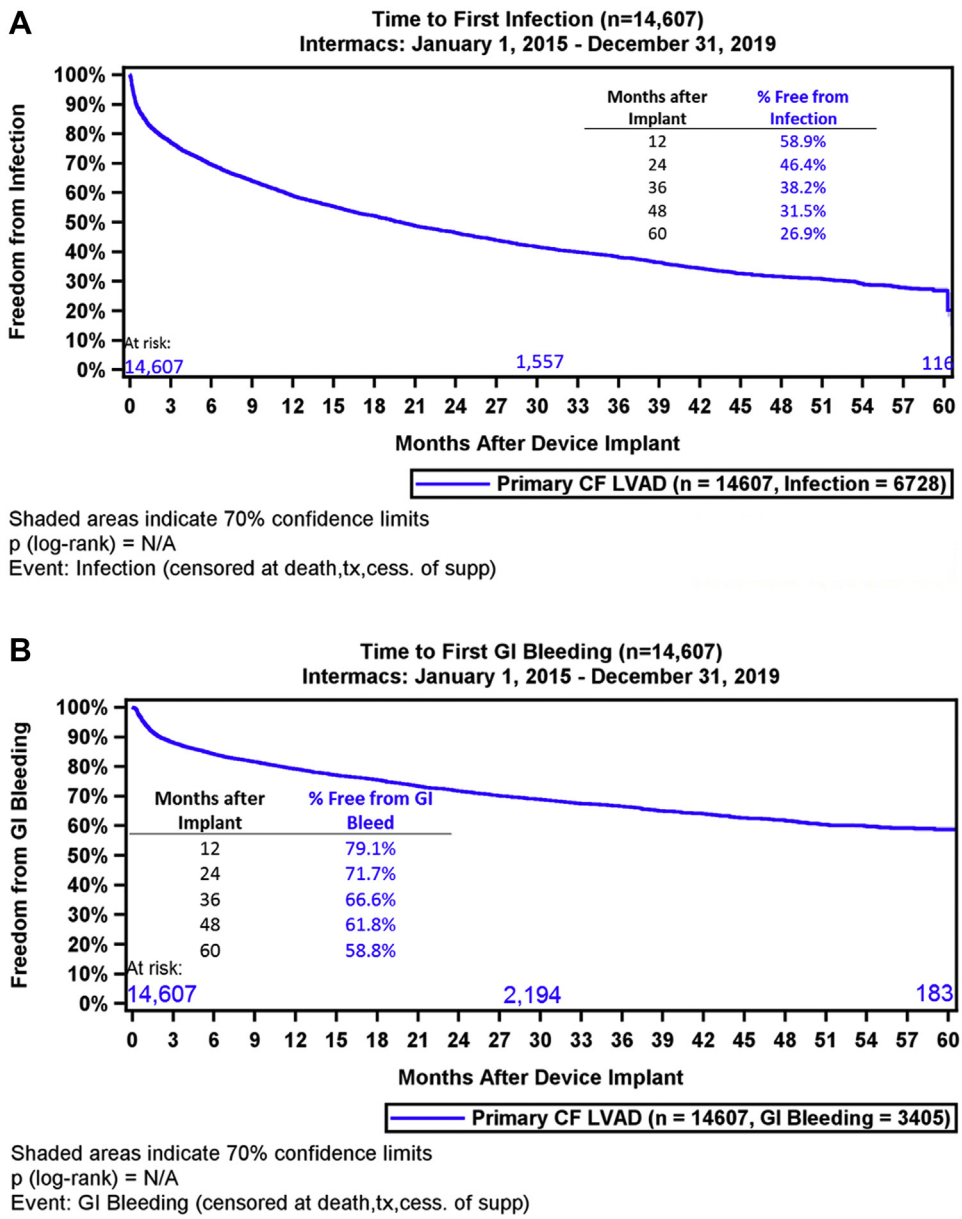


FIGURE 6 Freedom from adverse events. Time to (A) first major infection, (B) gastrointestinal (GI) bleeding, (C) stroke, and (D) rehospitalization. (CF LVAD, continuous flow left ventricular assist device; NA, not applicable; tx, transplant.)

Continued on the next page

months) in the previous era to 54.6 months (95% CI: 52.1%, 58.2% months) in the current era.

A stepwise improvement in survival is noted from Profile 1 to 2 to 3 ($P < .0001$) (Figure 4A). The survival curves largely overlap for Profiles 3 and 4 to 7 ($P > .999$). Survival according to INTERMACS Profile appears to be improving over time, with all Profiles in the contemporary era demonstrating small improvements in average survival after the first year of implant (Figure 4A and Supplemental Figures 7 and 8).

Survival stratified by device strategy and by era is shown in Figure 4B and Supplemental Figures 9 and 10. One-year survival for the most recent era is 86.8% for BTT, 83.8% for BTC, and 80.1% for DT ($P < .0001$). With DT being the predominant implant strategy in the last decade, there has been a gradual increase in patient support durations (Figure 5A, 5B, 5C and Supplemental Figures 11 to 19). In the previous era, the proportion of patients remaining on device support was surpassed by patients who died or had received a

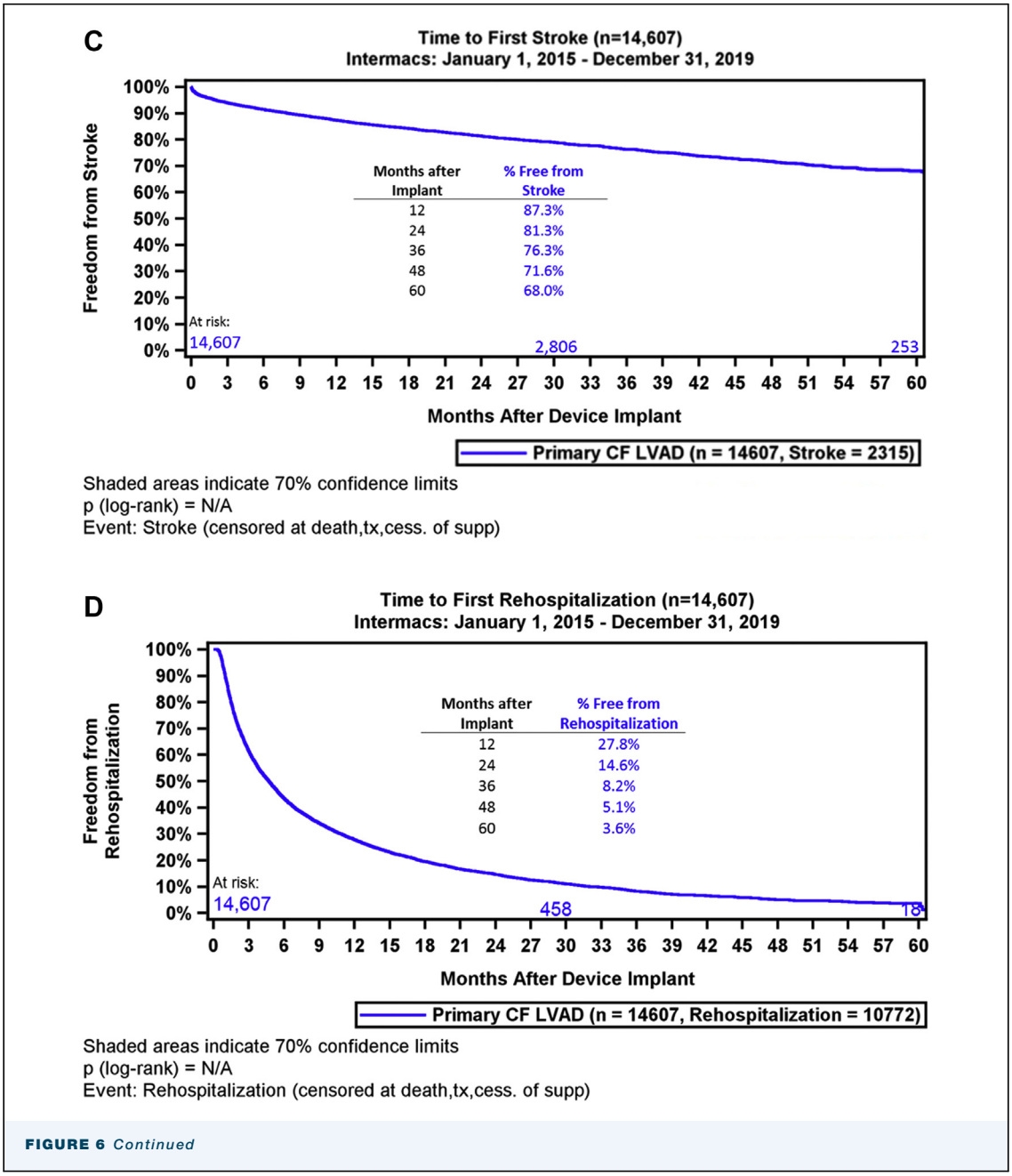


FIGURE 6 *Continued*

transplant at approximately 36 months (Supplemental Figure 12). In the present era, this time frame has shifted out to 42 months (Figure 5A). At 5 years, the proportions of initial BTT, BTC, and DT patients receiving a heart transplant were 61.3%, 40.7%, and 17.0%, respectively.

ADVERSE EVENTS AND REHOSPITALIZATIONS IN PATIENTS ON PRIMARY ISOLATED LVAD SUPPORT. The hazard for adverse events in the most recent era (2015-2019) continues to be highest in the early postoperative period (≤90 days) and diminishes significantly thereafter (Table 2). A notable exception is device-specific infection, which consists predominantly of driveline infections, where the early (≤90 days) and late (>90 days) event rates are 0.159 events per patient-year and 0.165 events per patient-year, respectively. The most common adverse events in the early and late periods after CF LVAD implant are major infection (early, 1.349; late, 0.440 events per patient-year) and major bleeding (early, 1.433; late, 0.347 events per patient-year). Only 59% and 67% of patients are free from infection (Figure 6A) and major bleeding (Supplemental Figure 20) at 1

TABLE 2 Adverse Events in 14,607 Patients on Isolated Continuous-Flow Left Ventricular Assist Device Support (January 1, 2015-December 31,2019) With Follow-up Through June 30, 2020

Event	Period[a]	Event Count	CF LVAD AE Rate[b]	Patient Count	Patient %
Rehospitalization (all cause)	Early	8200	2.419	5406	37.0
	Late	36,717	1.830	9630	65.9
Arterial non-CNS thromboembolism	Early	82	0.024	80	0.5
	Late	51	0.003	48	0.3
Major bleeding	Early	4859	1.433	3267	22.4
	Late	6960	0.347	3319	22.7
GI bleeding	Early	2368	0.699	1702	11.7
	Late	4996	0.249	2403	16.5
Non-GI reoperation for bleeding	Early	823	0.243	742	5.1
	Late	203	0.010	185	1.3
Cardiac arrhythmia	Early	3365	0.993	2574	17.6
	Late	2375	0.118	1561	10.7
Device malfunction/pump thrombus	Early	979	0.289	832	5.7
	Late	3133	0.156	2162	14.8
Device malfunction	Early	408	0.120	369	2.5
	Late	1522	0.076	1173	8.0
Pump thrombus	Early	622	0.183	532	3.6
	Late	1740	0.087	1288	8.8
Major infection	Early	4573	1.349	3382	23.2
	Late	8824	0.440	4654	31.9
Device-related infection	Early	1131	0.334	1015	6.9
	Late	2618	0.130	1817	12.4
Device-specific infection	Early	538	0.159	503	3.4
	Late	3302	0.165	2126	14.6
Nondevice infection	Early	3398	1.002	2625	18.0
	Late	4165	0.208	2697	18.5
Hepatic dysfunction	Early	277	0.082	268	1.8
	Late	246	0.012	226	1.5
Myocardial infarction	Early	33	0.010	33	0.2
	Late	50	0.002	45	0.3
Neurologic dysfunction	Early	1656	0.489	1462	10.0
	Late	2820	0.141	2094	14.3
Stroke	Early	998	0.294	913	6.3
	Late	1884	0.094	1526	10.4
Pericardial drainage	Early	532	0.157	477	3.3
	Late	15	0.001	14	0.1
Renal dysfunction	Early	1409	0.416	1305	8.9
	Late	845	0.042	697	4.8
Respiratory failure	Early	2352	0.694	1903	13.0
	Late	845	0.042	707	4.8
Venous thromboembolism	Early	249	0.073	231	1.6
	Late	62	0.003	61	0.4
Wound dehiscence	Early	140	0.041	129	0.9
	Late	64	0.003	59	0.4
Other serious AE	Early	3809	1.124	2437	16.7
	Late	3351	0.167	2005	13.7

[a]Early indicates ≤90 days after implant; late, >90 days after implant; [b]Rates are reported per patient–year.

AE, adverse event; CF LVADs, continuous flow left ventricular assist devices; CNS, central nervous system; GI, gastrointestinal.

TABLE 3 Causes of Death Comparison by Era for Patients on Isolated Left Ventricular Assist Device Support

Primary Cause of Death	Era 2010-2014[a] (n = 10,944)	Era 2015-2019[a] (n = 14,607)
Bleeding	84 (1.9)	80 (2.0)
Circulatory other	308 (7.0)	251 (6.3)
Device malfunction	171 (3.9)	55 (1.4)
Heart failure	519 (11.8)	496 (12.5)
Major infection	376 (8.5)	225 (5.7)
Multisystem organ failure	617 (14.0)	654 (16.4)
Neurologic dysfunction	845 (19.1)	622 (15.6)
Other	578 (13.1)	606 (15.2)
Respiratory	281 (6.4)	200 (5.0)
Sudden death	199 (4.5)	116 (2.9)
Withdrawal of support	437 (9.9)	677 (17.0)

[a]$P < .0001$ for all comparisons.

year, respectively, and approximately 50% of bleeding episodes are gastrointestinal in nature (Figure 6B). The current era shows a freedom from stroke of 87% at 1 year (Figure 6C). Time to the first nongastrointestinal reoperation for bleeding, device-specific infection, device-related infection, nondevice infection, neurologic dysfunction, development of pump malfunction, and pump thrombus is shown in Supplemental Figures 21 to 28.

Hospital readmissions remain a significant limitation of device therapy. Readmission after CF LVAD implant occurs in 38.6% (70% CI: 38.1%, 39.0%) of patients at 90 days and in 72.2% (70% CI: 71.8%, 72.6%) at 12 months (Figure 6D). The rate of readmission moderately improves between the early and late periods after CF LVAD implant (2.419 vs 1.830 events per patient-year; Table 2).

CAUSES OF DEATH FOR PATIENTS ON ISOLATED LVAD SUPPORT. In contrasting eras, there have been notable changes in the causes of death among CF LVAD recipients (Table 3). The incidence of death due to device malfunction has dropped from 3.9% to 1.4%, while major infection leading to death has declined from 8.5% to 5.7%. Importantly, neurologic dysfunction is no longer the reported leading cause of death. The proportion of patients dying of neurologic dysfunction has dropped from 19.1% to 15.6% between eras 1 and 2.

Despite these improvements, heart failure, stroke, multisystem organ failure, and major infection contribute to at least 50% of all deaths. As the LVAD indication has shifted toward DT in recent years, the number of patients dying after withdrawal of support

TABLE 4 The Society of Thoracic Surgeons-Interagency Registry for Mechanically Assisted Circulatory Support Research Published in 2019

Title	Aims	Key Findings
Center variation in Medicare spending for durable left ventricular assist device implant hospitalizations (Thompson et al, *JAMA Cardiol*)[4]	To determine whether Medicare spending on hospitalizations for durable LVAD implants varies across centers and whether spending variation is associated with clinical outcomes (4442 patients at 106 centers, Jan 2008-Dec 2014)	Price-standardized and risk-standardized Medicare spending varied by 35% between the lowest and highest spending quartile centers, which was primarily driven by differences in outlier payments between hospitals. Patients treated in higher-spending hospitals had longer postimplant length of stay but similar clinical outcomes. The authors concluded that as the supply and demand for durable LVAD therapy continues to rise, identifying opportunities to reduce variation in spending from both explained and unexplained sources will ensure high-value use.
Factors associated with prolonged survival in left ventricular assist device recipients (Xia et al, *Ann Thorac Surg*)[5]	To identify patient characteristics and complications associated with prolonged survival (1116 patients, May 2012-Mar 2013).	Among patients who survived past the initial 6 months, 65% survived beyond 3 years. On univariate analysis, long-term survivors were significantly younger, were less likely to be White, supported for destination therapy, have diabetes, have solid-organ cancer, or receive amiodarone. On multivariate analysis, factors associated with increased odds of death at 3 years included diabetes, amiodarone use, and developing stroke, gastrointestinal bleeding, hemolysis, or pump thrombosis within 6 months of implantation.
Stroke and death risk in ventricular assist device patients varies by ISHLT infection category: an INTERMACS analysis (Shah et al, *J Heart Lung Transplant*)[6]	To analyze the correlation between infection and stroke (16,597 patients, Apr 2008-Dec 2016)	Infection occurred in 42% of study patients, of which 49% were non-VAD infections, 26% were VAD-related infections, and 25% were VAD-specific infections. One-year mortality (infection 29% vs no infection 13%) and overall stroke prevalence (18% vs 11%) were higher in patients who had any infection. Stroke rates were lowest in patients with a VAD-specific infection (0.11 EPPY) compared with VAD-related (0.17 EPPY) and non-VAD infections (0.15 EPPY). Patients with an infection were more likely to have hemorrhagic vs ischemic strokes across all infection subtypes. Rates of hemorrhagic strokes were highest after a VAD-related infection (0.13 EPPY). These results underscore the necessity of rapidly advancing fully implantable pump technologies as well as the need for close clinical monitoring of CF LVAD patients after an infection diagnosis.
End of life for patients with left ventricular assist devices: Insights from INTERMACS (McIlvennan et al, *J Heart Lung Transplant*)[7]	To identify where LVAD patients died, characterize QOL before death, and identify cause of death over time (18,733 patients, Jan 2008-Dec 2016).	Overall, 76.9% of the investigated patients died in the hospital. Progressively more patients dying outside of the hospital further post-LVAD implant: <1 month, 2.3%; 1 to 12 months, 16.8%; and >12 months, 37.4%. In a multivariable analysis, increased age (RR, 1.06) and destination therapy indication (RR 1.15) increased the likelihood of dying outside the hospital. When QOL 3 months postimplant was compared with 6 months before death in a subset of patients, QOL remained clinically stable. The most common cause of death <1 month postimplant was multiple-organ failure (20.4%) and at >1 month postimplant was neurologic dysfunction (28.2%).
Pre-implant phosphodiesterase-5 inhibitor use is associated with higher rates of severe early right heart failure after LVAD implantation: an INTERMACS analysis (Gulati et al, *Circ Heart Fail*)[8]	To investigate the association between preoperative PDE5i use and early right-sided heart failure after LVAD implantation (11,544 patients, Jan 2012-Dec 2017).	Patients on PDE5i had higher pulmonary artery systolic pressure and pulmonary vascular resistance. Before propensity matching, the incidence of severe early right-sided heart failure was higher among patients on PDE5i than in controls (29.4% vs 23.1%; unadjusted OR, 1.32). This association persisted after propensity matching (PDE5i, 28.9% vs control 23.7%; OR, 1.31), driven by a higher incidence of prolonged inotropic support. Similar results were observed across a wide range of subgroups stratified by markers of pulmonary vascular disease and right ventricular dysfunction.
Impact of obesity on ventricular assist device outcomes (Jaiswal et al, *J Card Fail*)[9]	To determine the clinical outcomes of obese patients with BMI ≥35 kg/m^2 (17,095 patients, June 2006-June 2014).	BMI >35 kg/m^2 in 15% of the cohort. Obese patients were more likely to be young, non-White, females, have dilated cardiomyopathy, and undergo device implantation as destination. Survival was similar among BMI groups. Obese patients had significantly higher risk for infection (HR, 1.21) device malfunction or thrombosis (HR, 1.32), cardiac arrhythmia (HR, 1.18), and hospital readmissions (HR, 1.07), but lower risk of bleeding (HR, 0.90). Significant weight loss (10%) during LVAD support was achieved only by a small proportion (18.6%) of patients with BMI >35 kg/m^2. Obese patients with significant weight loss were more likely to undergo cardiac transplantation.
Clinical outcomes after left ventricular assist device implantation in older adults: an INTERMACS analysis (Caraballo et al, *JACC Heart Fail*)[10]	To investigate outcomes in older adults >75 years of age (20,939 patients, Jan 2008-Dec 2017).	The main findings of this study were the following: (1) older adults undergoing LVAD implantation had fewer concomitant conditions than younger patients, yet still had increased mortality; (2) older patients had higher bleeding risk but lower risk for device thrombosis; (3) there was an increased need for rehabilitation postdischarge in older adults receiving LVADs (49.8% vs 13.2% of those <55 years); and (4) malnutrition, poor functional capacity, and need for RVAD support were predictors of early adverse outcomes in older adults.
Outcomes based on blood pressure in patients on continuous flow LVAD support: an INTERMACS analysis (Cowger et al, *J Heart Lung Transplant*)[11]	To evaluate overall survival and the incidence of stroke, right ventricular failure, infection, and/or renal failure according to BP results (16,155 patients, Jan 2006-Dec 2015).	Patients with chronically low MAP (≤75 mm Hg), Doppler opening BP (≤80 mm Hg), and systolic BP (<90 mm Hg) had 35%-42% higher adjusted hazards of death than patients with normal or high BP. On multivariable analyses, extreme hypertension was also associated with higher mortality, whereas the correlations between hypertension and neurologic and thrombotic events were inconsistent in the total CF LVAD sample and by device flow profile. These results underscore the importance of BP monitoring during CF LVAD support, aiming for a MAP >75 but <90 mm Hg. While hypertension remains an important clinical target for reducing stroke, pump thrombosis, and mortality risks during CF LVAD, the findings support the need to identify other key factors contributing substantial attributable risks for stroke during CF LVAD support.
Outcomes of Asian-Americans implanted with left ventricular assist devices: an INTERMACS analysis (Taleb et al, *Heart Lung Circ*)[12]	To compare the clinical outcomes after LVAD implantation in Asians vs Whites (7108 patients, June 2006-June 2015).	There were 130 patients identified as Asian Americans. Asian Americans were younger, had lower BMI, higher serum bilirubin, and lower albumin levels. In a multivariable regression model, there was no difference in survival between the 2 groups. Asian Americans had lower incidence of device malfunction even after adjusting for multiple factors. The adjusted risk of a major safety composite outcome, including major bleeding, major infection, stroke, and device malfunction, demonstrated no differences between the 2 groups.

BMI, body mass index; BP, blood pressure; CF LVAD, continuous flow left ventricular assist device; EPPY, events per patient-year; HR, hazard ratio; INTERMACS, Interagency Registry for Mechanically Assisted Circulatory Support; ISHLT, International Society for Heart and Lung Transplantation; MAP, mean arterial pressure; OR, odds ratio; PDE5i, phosphodiesterase 5 inhibitor; QOL, quality of life; RR, risk ratio; RVAD, right ventricular assist device; VAD, ventricular assist device.

(17.0%) has risen significantly, and withdrawal of care is now the number 1 cause of death reported to the Registry, replacing stroke in cumulative incidence. Whether these findings are the result of patients dying of other medical comorbidities or wishing to terminate support due to failure to thrive in the setting of device-related issues warrants further study. Further differentiation of this end point will be important in future Registry analyses.

2019 STS-SPONSORED INTERMACS RESEARCH AND STUDIES FROM THE PARTICIPANT USER FILE PROGRAM

In 2019, the STS-Intermacs database contributed 9 publications toward the advancement of science in the durable MCS field (Table 4).[4-12] All 2019 publications were investigator analyses using the Participant User File Research Program pathway available at https://www.sts.org/registries-research-center/sts-research-center/participant-user-file-research-program. After the Intermacs transition to STS in 2018, the Access & Publication Program was created as a second avenue of sponsored and funded data analyses administered by the STS Access & Publication Task Force. Analysis of Access and Publication-approved proposals are performed by STS statistical experts from the data coordinating center at the University of Alabama at Birmingham. A list of current projects and a link to the Access & Publication proposal application can be found at www.sts.org/registries-research-center/sts-research-center/funded-research.

STS-INTERMACS QUALITY INITIATIVE. STS-Intermacs has undertaken a new initiative on quality assessment and reporting. Over the next several years, STS-Intermacs aims to devise a multifaceted CF LVAD-specific quality outcome, inclusive of survival, key adverse events, and patient reported outcome measures for assessing short-term and long-term outcomes on CF LVAD support. Active development of cardiac recovery efforts could be part of these important quality metrics. This multifaceted measure of "LVAD success" will be reported annually, helping to drive research and device engineering toward key outcomes that will have the greatest impact on long-term LVAD outcomes. In addition, this measure can be provided individually to LVAD implanting centers, providing a graphic representation of a center's longitudinal performance in crucial quality metric trajectories (eg, individual measures of survival, quality of life, and stroke over time) as well as the implanting center's composite quality score over time. Ultimately, STS aims to provide centers with benchmarked Intermacs comparisons using composite scores from similar centers, matched according to key characteristics (eg, implant volume, payor mix, and transplant capacities).

STS SPECIAL REPORTS IN MCS. In addition to the annual summary of outcomes in patients on durable MCS, STS has enacted a new series of special reports. Annually, a variable number of Intermacs registry analyses will be undertaken, addressing key clinical questions in patients supported with MCS. Topics may be STS- or investigator-initiated, but all proposals will complete a formal STS Access & Publication Research Program vetting process, and data analyses will be supported through the Data and Clinical Coordinating Center. The first 2 special reports will address the specific aims of defining optimal outcomes after CF LVAD support and comparing patient mortality and adverse events based on CF LVAD flow profile. Further information on Intermacs Special Reports can be found at www.sts.org.

SUMMARY

With the evolution of device engineering and improvements in patient selection and care, average survival in patients designated for permanent support is now approaching 5 years. The highest risk for mortality and complications continues to occur in the first 3 months after device implantation, supporting the need for ongoing event reporting in short-term and longer-term windows of risk. Hospitalization and serious adverse event burdens remain high after CF LVAD, with stroke, infection, multisystem organ failure, and heart failure contributing the greatest attributable risk to mortality. Stroke has historically been the leading cause of long-term mortality after CF LVAD implant. As the proportion of patients receiving newer-generation pumps increases, we expect to see a gradual improvement in stroke rates as outlined in the 2019 report.[1] Withdrawal of care has recently become the leading cause of death in this patient population, a finding that warrants further scientific investigation and clarification. The focus of STS-Intermacs in ensuing years will be to define a multifaceted benchmark for LVAD success that underscores major morbidities, patient-reported outcome measures, and truly long-term (eg, 5-year) outcomes.

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