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Contemporary outcomes after 100 consecutive HeartMate 3 LVAD implantations: a single-centre cohort study from a Swiss tertiary centre

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Summary

INTRODUCTION: The HeartMate 3 left ventricular assist device (LVAD) is an established therapy for advanced heart failure, yet contemporary real-world data from low- or medium-volume centres remain limited. We aimed to describe the characteristics, management and clinical outcomes of patients undergoing HeartMate 3 LVAD implantation at a Swiss tertiary centre.

METHODS: We conducted an observational study including consecutive adult patients who underwent HeartMate 3 implantation at Lausanne University Hospital between November 2015 and January 2026. Baseline characteristics, INTERMACS profiles, perioperative data, survival and LVAD-related complications were assessed. The primary outcome was survival on LVAD support. Comparisons by LVAD indication were pre-specified exploratory analyses (destination therapy vs bridge-to-transplant). Survival analyses on LVAD support, with heart transplantation or LVAD explantation treated as censoring events, were reported.

RESULTS: A total of 100 patients (mean age 58 [standard deviation 12] years, 84% male, 29% destination therapy) underwent HeartMate 3 implantation. Ischaemic heart disease was the predominant aetiology (69%) and most patients (68%) were classified as INTERMACS profiles 3–4 at implantation. Over a median follow-up of 1.5 (IQR 0.5–3) years, 27 patients died on LVAD support, corresponding to a mortality incidence rate (IR) of 13.5 deaths per 100 patient-years, while 51 patients underwent heart transplantation, corresponding to an IR of transplantation of 25.4 per 100 patient-years. Five-year survival on LVAD support was 64%, with patients censored at LVAD explantation for recovery or transplantation. LVAD-related complications included bleeding (48%), infection (50%), ischaemic stroke (12%) and right ventricular failure (39%). Survival did not differ by LVAD indication (bridge-to-transplant as reference, adjusted HR 0.62, 95% CI 0.14–2.72).

CONCLUSIONS: In this contemporary, real-world, medium-sized cohort, HeartMate 3 therapy provided durable long-term support across a broad spectrum of advanced heart failure patients, with outcomes consistent with those reported in large multicentre registries.

Introduction

Heart failure remains associated with substantial morbidity and mortality despite major advances in contemporary medical and device therapies that have improved outcomes over recent decades [1-3]. A subset of patients progresses to advanced heart failure, characterised by refractory symptoms, severe functional limitation, recurrent hospitalisations, poor survival and frequent intolerance to guideline-directed medical therapy [4]. For these patients, advanced therapies – namely heart transplantation or durable mechanical circulatory support with left ventricular assist devices

(LVAD) – represent the only effective long-term treatment options for those who are eligible [5, 6]. Over the past decade, technological refinements in pump design and haemocompatibility have markedly improved the safety and durability of LVAD therapy, reducing pump thrombosis, stroke and device malfunction while enhancing survival [7].

The fully magnetically levitated centrifugal-flow HeartMate 3 (Abbott, Abbott Park, IL, USA) represents the current standard of care in durable LVADs. The MOMENTUM 3 (Multicenter Study of MagLev Technology in Patients Undergoing Mechanical Circulatory Support Therapy with HeartMate 3) trial and large registry analyses have demonstrated superior outcomes compared with previous-generation devices, with improved survival free from disabling stroke or pump replacement and lower rates of haemocompatibility-related adverse events [8-10]. As a result, this device has become the predominant platform for long-term mechanical circulatory support, used both as bridge-to-transplant (BTT) and as destination therapy (DT) in patients ineligible for heart transplantation.

Most contemporary outcome data originate from highly specialised, high-volume North American centres and from the pivotal randomised MOMENTUM 3 trial [8-11]. Whether these outcomes can be consistently reproduced in routine practice, particularly in smaller European centres outside very high-volume programmes, remains uncertain. Real-world cohorts outside high-volume programmes may differ substantially in referral patterns, patient selection, perioperative management and resource allocation, all of which may influence outcomes [12]. Furthermore, data from low- or medium-volume European tertiary centres remain scarce, and participation in registries such as EUROMACS (European Registry for Patients with Mechanical Circulatory Support) is voluntary, which may limit the completeness of real-world outcome capture compared with North America [13].

Therefore, we sought to describe the clinical characteristics, management, clinical outcomes and adverse events of the first 100 consecutive adult patients undergoing HeartMate 3 implantation at Lausanne University Hospital, building on our centre's previously reported experience [14, 15], and to contextualise these real-world results within the contemporary literature.

Methods

Study population

We conducted a single-centre observational cohort study including all consecutive adult patients who underwent implantation of the centrifugal-flow HeartMate 3 LVAD at Lausanne University Hospital *(Centre hospitalier universitaire vaudois)* between November 2015 and January 2026. The programme performed its first HeartMate 3 implantation in November 2015 and subsequently, in 2022, was designated as a national centre for highly specialised LVAD therapy. Our institution received official authorisation to perform LVAD implantation for DT in 2017 [16]. Lausanne University Hospital serves as a tertiary referral and teaching centre providing comprehensive care for advanced heart failure across Western Switzerland.

Briefly, candidates typically presented with advanced symptoms (New York Heart Association class [NYHA] IIIb–IV), severely reduced left ventricular ejection fraction (LVEF; ≤25%) and impaired cardiac output (cardiac index ≤2.2 l/min/m²), despite guideline-directed medical therapy or owing to an inability to tolerate such therapy; and were dependent on inotropic support or listed for heart transplantation according to international recommendations [2, 4, 17]. As part of local institutional practice, durable LVAD implantation was generally not offered to patients aged over 75 years.

To reflect real-world clinical practice, no additional inclusion or exclusion criteria were applied in our study. Both BTT and DT indications were included. Clinical data were collected under the hospital's general consent framework for secondary use of routinely acquired health information, and patients were included unless they had formally declined participation.

Organisation of care and patient pathway

LVAD care was delivered within a dedicated advanced heart failure and transplant unit comprising two senior attending physicians, two chief residents, two residents and three specialised heart-transplant and LVAD nurses, working in close collaboration with the institutional organ transplant coordination team. Patients with advanced heart failure were identified and longitudinally followed by the unit's physicians and specialised nurses.

In eligible patients, a comprehensive pre-LVAD evaluation was undertaken, either performed electively during a planned hospitalisation in stable ambulatory patients or on an expedited, individualised timeline in patients already in intensive care or haemodynamically unstable. For each case, candidacy and indication (BTT versus DT) for LVAD therapy or heart transplantation were systematically assessed at a multidisciplinary heart-team conference in collaboration with colleagues from Geneva University Hospitals, involving heart failure cardiologists, cardiac surgeons, anaesthetists, intensivists and specialised LVAD nurses, with palliative care physicians, geriatricians, nephrologists and other specialists involved according to the patient's profile.

Following approval, HeartMate 3 implantation was scheduled electively. Postoperatively, patients were admitted to the intensive care unit for close multidisciplinary monitoring under standardised institutional protocols for anticoagulation, right ventricular support (use of temporary right ventricular assist device support when clinically indicated) and driveline care. They were subsequently stepped down to an intermediate care unit and then to the cardiac surgery ward, during which structured LVAD education and self-care training were provided to patients and their caregivers, followed by an inpatient cardiac rehabilitation programme (La Lignière Clinic). After discharge, patients entered a structured outpatient surveillance programme led by the unit's physicians and specialised nurses, with more frequent visits (every two to three weeks) during the early post-discharge phase, subsequently spaced to approximately every four weeks once clinically stable, supported by round-the-clock access to the on-call LVAD team, shared care with referring cardiologists, and standardised protocols for driveline wound care and infection prevention. The organisation of the unit and the patient pathway are summarised in figure S1 in the appendix.

Data collection and outcomes

Baseline demographic and clinical characteristics, heart failure aetiology, comorbidities and INTERMACS (Interagency Registry for Mechanically Assisted Circulatory Support) profiles at implantation [18], as well as intra- and perioperative variables and longitudinal follow-up data, were systematically collected from institutional electronic health records and entered into a dedicated and anonymised database. Data were retrospectively extracted for analysis, and completeness and accuracy were independently verified by two study investigators (AN and TA).

Preoperative clinical status was determined within the 24 hours preceding HeartMate 3 implantation and classified according to INTERMACS definitions. Patients presenting with acute cardiogenic shock who were initially stabilised with venoarterial extracorporeal life support and subsequently recovered end-organ function were categorised as INTERMACS profile 2. Ambulatory patients requiring repeated scheduled inotropic support, including intermittent levosimendan infusions, were classified as INTERMACS profile 4.

Adverse events were adjudicated according to standardised criteria from the Mechanical Circulatory Support Academic Research Consortium [19]. Postoperative infections were categorised as device-specific (e.g. infections directly involving LVAD components) or device-related (e.g. systemic or bloodstream infections occurring in the context of LVAD support but not directly involving the device). Driveline infection was defined by local inflammatory signs or drainage at the exit site associated with positive microbiological cultures. Bleeding outcomes were classified as follows: overall bleeding events were defined as any clinically relevant bleeding requiring medical evaluation, hospitalisation, transfusion of blood products or procedural/surgical intervention; major bleeding as events requiring surgical or procedural intervention and/or transfusion; and gastrointestinal bleeding as overt gastrointestinal haemorrhage requiring hospitalisation, transfusion or endoscopic, radiological or surgical treatment.

The primary outcome was survival on LVAD support, defined as time from implantation to death, with heart transplantation or device explantation for myocardial recovery treated as censoring events. In a prespecified sensitivity analysis, overall all-cause mortality was estimated using the Kaplan-Meier method, with transplantation treated as a non-censoring event: patients who underwent transplantation remained in the risk set, and deaths occurring after transplantation were included as events. This analysis was intended to capture total mortality burden irrespective of subsequent transplant or device status. Secondary outcomes included the incidence of LVAD-related adverse events (bleeding, infection, stroke, right ventricular failure and acute kidney injury) and exploratory comparisons of survival and complication rates according to LVAD indication (BTT versus DT). In another exploratory analysis, survival was compared according to INTERMACS profile at implantation, categorised as profiles 1–2 versus 3–5.

Statistical analyses

Continuous variables are presented as mean (standard deviation [SD]) or median with interquartile range (IQR), as appropriate. Categorical variables are reported as counts and percentages. Group comparisons were performed using the Student's t-test or Wilcoxon rank-sum test for continuous variables and the χ^2 or Fisher's exact test for categorical variables, as appropriate.

Survival on LVAD support was estimated using the Kaplan–Meier method. Reported survival percentages at specific time points were derived directly from the cumulative survival function. Survival comparisons between LVAD indications (e.g. between BTT and DT) were performed using Cox proportional hazards regression, with results reported as hazard ratios (HR) and 95% confidence intervals (CI). Multivariable models were adjusted for covariates selected a priori based on clinical relevance and known prognostic significance in LVAD recipients, along with characteristics that differed significantly between groups at baseline. The following variables were included: age at implantation, sex, baseline estimated glomerular filtration rate, INTERMACS profile at implantation and post-implant right ventricular failure. All continuous variables (age, baseline eGFR [estimated glomerular filtration rate]) were modelled as linear terms. INTERMACS profile was modelled as a continuous ordinal variable. Sex, LVAD indication and post-implant right ventricular failure were modelled as binary variables. We tested for violation of the proportional hazards assumption for all HRs that were reported via Schoenfeld residuals.

All tests were two-sided and a p-value <0.05 was considered statistically significant. All analyses were carried out using Stata version 18.0 (StataCorp, College Station, TX, USA).

Ethics statement and patient consent statement

This study was conducted in accordance with the Declaration of Helsinki and received approval from the relevant local ethics committees (CER-VD 2025-01851).

Results

Patient characteristics

A total of 100 LVAD implantations were performed between 2015 and 2026 (figure 1). Implant activity peaked in 2019–2020 and remained relatively stable thereafter. Across all periods, BTT (n = 65) was the predominant indication, whereas DT accounted for fewer implantations (n = 29). Other indications (bridge-to-candidacy, bridge-to-decision, bridge-to-recovery) were infrequent.

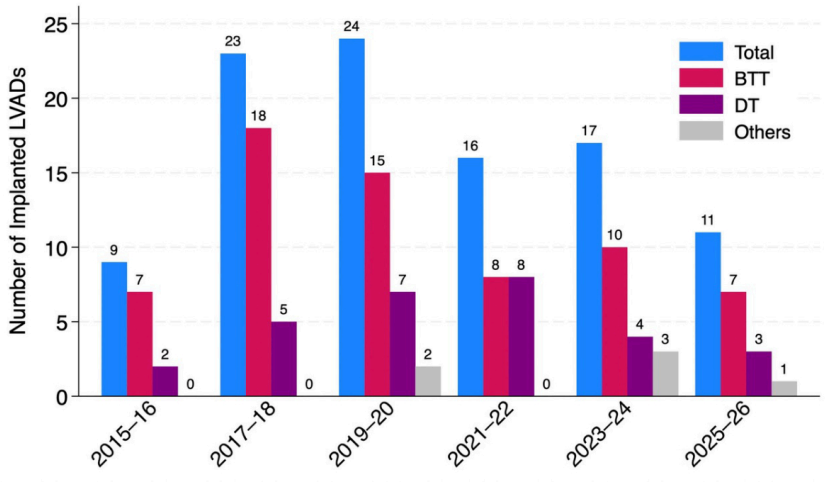


Figure 1: Temporal trends in HeartMate 3 LVAD implantations according to clinical indication, Lausanne University Hospital. X-axis: 2-year implantation periods from 2015–2016 to 2025–2026. "Others" includes BTC, BTD and BTR. Abbreviations: BTC: bridge-to-candidacy; BTD: bridge-to-decision; BTR: bridge-to-recovery; BTT: bridge-to-transplant; DT: destination therapy; LVAD: left ventricular assist device.

The mean age at implantation was 58 (12) years, and 84% of patients were male. Ischaemic heart disease was the predominant heart failure aetiology (69%). Clinical status at implantation reflected advanced disease: 68% were INTERMACS profile 3–4 and 30% were in cardiogenic shock (profiles 1–2), with 76% in NYHA class IV. Chronic kidney disease, diabetes and atrial fibrillation or flutter on baseline electrocardiogram were present in 51%, 29% and 15% of patients, respectively. Mean body mass index was 26.6 kg/m² and mean eGFR was 60.6 ml/min/1.73 m². Echocardiography showed severe left ventricular systolic dysfunction (LVEF 21 [7]%) with marked LV dilation, while haemodynamic assessment showed a cardiac index of 2.2 (0.4) l/min/m², with elevated pulmonary and LV filling pressures. Before LVAD implantation, 38% of patients required intensive care, 26% mechanical ventilation, 20% dialysis and 18% temporary mechanical circulatory support, most commonly venoarterial extracorporeal life support. Detailed baseline characteristics are presented in table 1.

Table 1: Baseline patient characteristics.

Parameters		**Overall cohort (n = 100)**
Age, years – mean (SD)		57.8 (12.3)
Male sex – n (%)		84 (84.0%)
HF aetiology – n (%)	Ischaemic aetiology	69 (69.0%)
	Non-ischaemic aetiology	31 (31.0%)
LVAD indication – n (%)	BTC	1 (1.0%)
	BTD	4 (4.0%)
	BTR	1 (1.0%)
	BTT	65 (65.0%)
	DT	29 (29.0%)
BMI, kg/m^2 – mean (SD)		26.6 (5.0)
eGFR, ml/min/1.73 m^2 – mean (SD)		60.6 (26.2)
CKD (eGFR <60 ml/min/1.73 m^2) – n (%)		51 (51.0%)
Atrial fibrillation/flutter on ECG – n (%)		15 (15%)
INTERMACS class – n (%)	1	16 (16.0%)
	2	14 (14.0%)
	3	28 (28.0%)
	4/5	42 (42.0%)
NYHA – n (%)	III	24 (24.0%)
	IV	76 (76.0%)
Diabetes – n (%)		29 (29.0%)
Carotid disease – n (%)		4 (4.0%)
SBP, mm Hg – mean (SD)		99.3 (15.3)
MAP, mm Hg – mean (SD)		76.6 (11.8)
Echocardiographic and haemodynamic data	LVEF, % – mean (SD)	21.1 (6.7)
	LVEDVi, ml/m^2 – mean (SD) (n = 83)	111 (43)
	LVESVi, ml/m^2 – mean (SD) (n = 77)	88 (39)
	Cardiac index, l/min/m^2 – mean (SD)	2.2 (0.4)
	mPAP, mm Hg – mean (SD)	33.6 (9.7)
	PCWP, mm Hg – mean (SD)	23.5 (7.8)
	PVR, Wood Units – mean (SD)	3.3 (7.1)
Preimplantation support	ICU – n (%)	38 (38.0%)
Temporary MCS – n (%)	ECLS	15 (15.0%)
	Impella 5.5	1 (1.0%)
	Berlin Heart EXCOR® device	2 (2.0%)
Dialysis – n (%) (n = 90)		18 (20.0%)
Mechanical ventilation – n (%)		26 (26.0%)

Abbreviations: AF: atrial fibrillation; BMI: body mass index; BTC: bridge-to-candidacy; BTD: bridge-to-decision; BTR: bridge-to-recovery; BTT: bridge-to-transplant; CKD: chronic kidney disease; DT: destination therapy; ECG: electrocardiogram; ECLS: extracorporeal life support; eGFR: estimated glomerular filtration rate; HF: heart failure; ICU: intensive care unit; INTERMACS: Interagency Registry for Mechanically Assisted Circulatory Support; LVEDVi: left ventricular end-diastolic volume indexed to body surface area; LVEF: left ventricular ejection fraction; LVESVi: left ventricular end-systolic volume indexed to body surface area; MAP: mean arterial pressure; MCS: mechanical circulatory support; mPAP: mean pulmonary arterial pressure; NYHA: New York Heart Association; PCWP: pulmonary capillary wedge pressure; PVR: pulmonary vascular resistance; SBP: systolic blood pressure.

Compared with BTT recipients, DT patients were older and had a higher comorbidity burden, including a greater prevalence of non-ischaemic heart failure aetiology, worse renal function, more carotid disease and higher pulmonary vascular resistance. In contrast, BTT patients were more frequently admitted to the intensive care unit (ICU) prior to implantation. No significant differences were observed for other baseline characteristics, including INTERMACS profile or NYHA class. Detailed comparisons are provided in table S1 in the appendix.

Perioperative procedures

In the overall cohort of 100 patients undergoing LVAD implantation, median sternotomy was the predominant surgical approach (89%), whereas left thoracotomy (4%) and double mini-thoracotomy (7%) were infrequently used (table 2). Mean cardiopulmonary bypass time was 72 (23) minutes and aortic cross-clamping was required in 6% of cases. Concomitant cardiac procedures included aortic valve replacement in 4% of cases and perioperative atrial septal defect closure in 9%. Perioperative characteristics were similar when stratified by LVAD indication, with comparable use of sternotomy between BTT and DT patients (88% vs 90%), similar bypass times (71 [23] vs 72 [21] minutes), and no significant differences in cross-clamping or additional procedures (table S2 in the appendix).

Table 2: Perioperative procedures.

Parameters		**Overall cohort (n = 100)**
Median sternotomy – n (%)		89 (89.0%)
Left thoracotomy – n (%)		4 (4.0%)
Double mini-thoracotomy – n (%)		7 (7.0%)
CPB time, min – mean (SD)		72.3 (23.1)
Aortic cross-clamp – n (%)		6 (6.0%)
Concomitant cardiac procedures	AV replacement – n (%)	4 (4.0%)
	Perioperative ASD closure – n (%)	9 (9.0%)

Abbreviations: AV: aortic valve; ASD: atrial septal defect; CPB: cardiopulmonary bypass.

Long-term outcomes and survival

Over a median follow-up of 1.5 (IQR 0.5–3) years, 27 deaths occurred on LVAD support, corresponding to an incidence rate of 13.5 per 100 patient-years, while 51 patients underwent heart transplantation (incidence rate of 25.4 per 100 patient-years). Causes of death were heterogeneous and are detailed in table S3 in the appendix. A 27-year-old woman with peripartum cardiomyopathy and cardiogenic shock underwent LVAD explantation 14 months later following recovery of LV function [20]. Kaplan-Meier estimates showed an approximate 1-year survival of 85% and 5-year survival of 64% on device support, with heart transplantation or explantation for myocardial recovery treated as censoring events (figure 2A). Survival on support did not differ significantly by indication (BTT vs DT, BTT as reference; HR 2.16, 95% CI 0.88–5.33; table 3, figure 2B), and this association was further attenuated after multivariable adjustment (adjusted HR 0.62, 95% CI 0.14–2.72). Findings were consistent in a sensitivity analysis excluding post-implant right ventricular failure (a post-baseline event more frequent in DT patients) from the adjustment set (adjusted HR 0.87, 95% CI 0.22–3.51). At 5 years, only 3 BTT and 9 DT patients remained at risk; Kaplan–Meier curves are presented up to 7 years to reflect the full available follow-up (figure 2B), although estimates beyond 4–5 years should be interpreted with caution given the limited number of patients at risk.

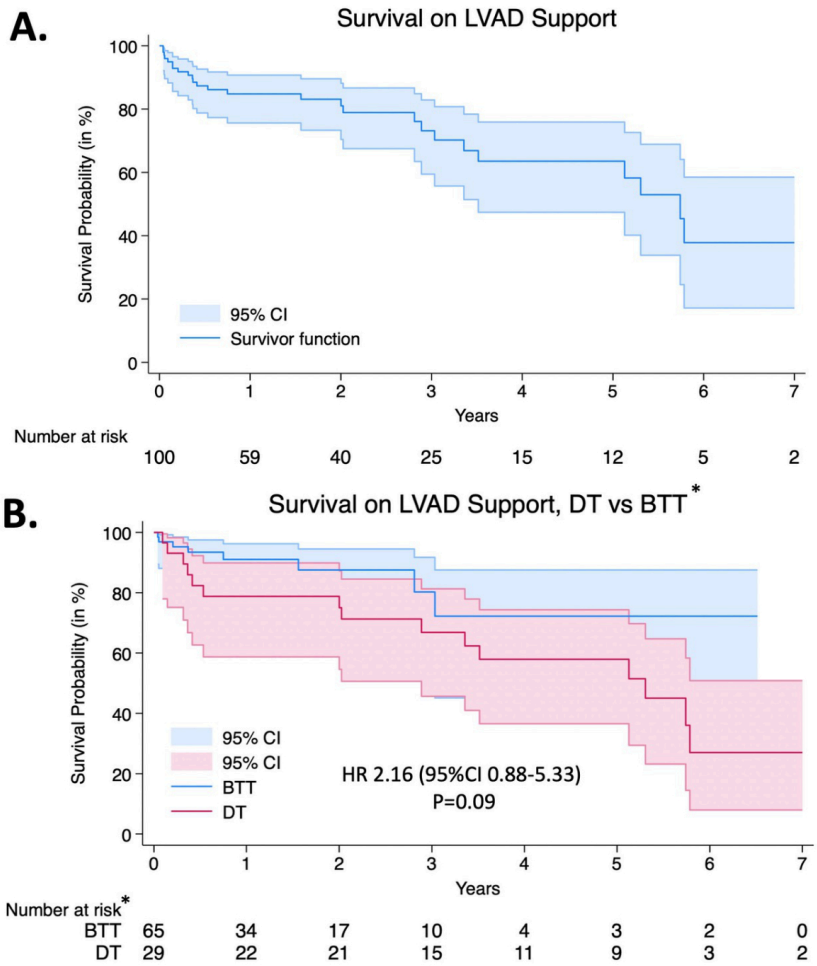


Figure 2: Survival on LVAD support, (A) Overall cohort, (B) According to indication (destination therapy vs bridge-to-transplant), Lausanne University Hospital. Patients who were explanted for heart transplantation or left ventricular function recovery (n = 52) were censored. *94 patients included (6 patients categorised as "Other than BTT or DT" excluded). Abbreviations: BTT: bridge-to-transplant; DT: destination therapy; LVAD: left ventricular assist device.

In the prespecified sensitivity analysis estimating overall all-cause survival – in which patients who underwent transplantation were not censored and deaths after transplantation were counted as events – 1-year and 5-year survival were 86% and 75%, respectively (figure S2A in the appendix). Overall survival differed significantly by indication, with worse outcomes in DT compared with BTT patients (HR 3.14, 95% CI 1.53–6.45; table 3, figure S2B in the appendix); however, this association was no longer significant after adjustment for the same variables as above (adjusted HR 1.00, 95% CI 0.31–3.22). In an exploratory analysis by INTERMACS profile at implantation, patients in profiles 1–2 (n=30) had significantly higher unadjusted mortality compared with those in profiles 3–5 (HR 3.22, 95% CI 1.35–7.71; p = 0.009). This association was attenuated and no longer statistically significant after multivariable adjustment (adjusted HR 1.56, 95% CI 0.52–4.72; p = 0.43).

No significant violations of the proportional hazards assumption with regards to the LVAD indication (BTT or DT) were detected.

Table 3: All-cause mortality events, event rates and hazard ratios comparing BTT with DT LVAD.

		Events, n (%)	Event rate per 100 py (95% CI)	Unadjusted HR (95% CI)	Adjusted HR* (95% CI)
Deaths on LVAD support**	BTT (n = 65)	8 (12.3%)	9.0 (4.0–16.0)	1 (reference)	1 (reference)
	DT (n = 29)	16 (55.2%)	16.9 (10.3–27.5)	2.16 (0.88–5.33)	0.62 (0.14–2.72)
Overall deaths (including after heart transplantation)	BTT (n = 65)	15 (23.1%)	5.0 (3.0–8.4)	1 (reference)	1 (reference)
	DT (n = 29)	16 (55.2%)	16.7 (10.2–27.2)	3.14 (1.53–6.45)	1.00 (0.31–3.22)

* Model adjusted for age, sex, eGFR at baseline, right heart failure after LVAD implantation, INTERMACS class.

** Patients who were explanted for heart transplantation or left ventricular function recovery (n = 52) were censored.

Abbreviations: BTT: bridge-to-transplant; DT: destination therapy; eGFR: estimated glomerular filtration rate; INTERMACS: Interagency Registry for Mechanically Assisted Circulatory Support; LVAD: left ventricular assist device; py: patient-years.

Postoperative complications during follow-up

Right ventricular failure occurred in 39% of patients, with 28% requiring temporary right VAD support for a mean duration of 7.7 (3.0) days (table 4). Haemocompatibility-related events included overall bleeding in 48%, major bleeding in 32% and gastrointestinal bleeding in 21%; no pump thrombosis was observed. LVAD-specific and LVAD-related infections occurred in 50% and 21% of patients, respectively. Neurological events included ischaemic stroke in 12% and haemorrhagic stroke in 3%; 19% of patients developed acute kidney injury requiring dialysis. Median ICU and total hospital lengths of stay were 10 (IQR 5–20) and 34 (IQR 25–67) days, respectively.

When stratified by LVAD indication, DT patients had higher rates of right ventricular failure (55% vs 29%, p = 0.016), overall bleeding (62% vs 39%, p = 0.046), gastrointestinal bleeding (38% vs 12%, p = 0.005) and haemorrhagic stroke (7% vs 0%, p = 0.034), with otherwise similar infection and renal complication rates and a trend towards longer ICU and overall hospital stays compared with BTT patients (table S4 in the appendix).

Table 4: Postoperative outcomes and adverse events.

Parameters		Overall cohort (n = 100)
Haemodynamic support	Right ventricular failure – n (%)	39 (39.0%)
	Temporary RVAD requirement – n (%)	28 (28.0%)
	Length of RVAD support, days – mean (SD)	7.7 (3.0)
Haemocompatibility-related adverse events	Pump thrombosis – n (%)	0
	Overall bleeding events – n (%)	48 (48.0%)
	Major bleeding – n (%)	32 (32.0%)
	GI bleeding – n (%)	21 (21.0%)
Infectious complications	LVAD-specific infection – n (%)	50 (50.0%)
	LVAD-related infection – n (%)	21 (21.0%)
Neurological events	Ischaemic stroke – n (%)	12 (12.0%)
	Haemorrhagic stroke – n (%)	3 (3.0%)
Renal complications	AKI requiring dialysis – n (%)	19 (19.0%)
Length of stay	ICU LOS, days – median (IQR)	10 (5–20)
	Overall LOS, days – median (IQR)	34 (25–67)

Abbreviations: AKI: acute kidney injury; GI: gastrointestinal; ICU: intensive care unit; LOS: length of stay; LVAD: left ventricular assist device; RVAD: right ventricular assist device.

Antithrombotic management

Throughout most of the study period, the standard institutional antithrombotic regimen consisted of a vitamin K antagonist (target INR 2.0–3.0) combined with low-dose aspirin (100 mg daily), initiated after the early postoperative period. Following publication of the ARIES-HM3 trial (Antiplatelet Removal and Hemocompatibility Events With the HeartMate 3 Pump) in 2023 [21], aspirin was no longer systematically prescribed: 72 patients were implanted before 2023 and 28 from 2023 onwards; among those with follow-up extending beyond 2023, aspirin was selectively withheld or discontinued on an individualised basis according to haemorrhagic and thrombotic risk.

Anticoagulation was managed by the advanced heart failure unit in coordination with the patient's referring physician. Detailed patient-level quantification of antithrombotic regimens over the full follow-up period was not available given the dynamic and individualised nature of these adjustments.

Discussion

In this single-centre, real-world cohort of 100 consecutive patients undergoing HeartMate 3 LVAD implantation, we observed durable clinical outcomes over mid- and long-term follow-up. Survival on device support was 85% at 1 year and 64% at 5 years, with a substantial proportion of patients (51%) subsequently undergoing heart transplantation. During follow-up, major adverse events included bleeding, infection and neurological complications, occurring at frequencies broadly consistent with contemporary data in continuous-flow LVAD recipients.

Regarding survival outcomes, our findings indicate that contemporary HeartMate 3 therapy provides durable long-term support in routine clinical practice, with outcomes consistent with those reported in pivotal studies and large registries. In the MOMENTUM 3 trial, survival reached 84% at 1 year and 52% at 5 years [9, 22], while real-world registries have reported 2-year survival of approximately 80–83% and 5-year survival between 58% and 63% with contemporary continuous-flow LVADs [23-25]. In comparison, our cohort achieved an estimated 1-year survival of 85% and a 5-year survival on device support of 64%, placing these results within the upper range of contemporary outcomes reported in international registries and trials. Importantly, these findings demonstrate that outcomes consistent with those reported in high-volume programmes can be achieved in a low-volume European centre, supporting the broader reproducibility and generalisability of contemporary LVAD therapy beyond ultra–high-volume institutions.

Our survival findings should be interpreted in light of differences in patient selection and baseline risk profiles across studies. For instance, contemporary INTERMACS registry data (2015–2019) show that nearly half of patients were implanted in cardiogenic shock (profiles 1–2) [26], whereas the MOMENTUM 3 trial enrolled a comparatively more stable population [8]. In our cohort, most patients were implanted in INTERMACS 3–5 profiles, with relatively few individuals in cardiogenic shock. In addition, a substantial proportion of patients underwent LVAD implantation as BTT, with 51 patients transplanted during follow-up. Using data from our cohort, we previously showed that a strategy of LVAD support prior to transplantation yields post-transplant outcomes comparable to those of direct heart transplantation [27]. The prominent use of a BTT strategy in our centre contrasts with recent US reports showing a growing predominance of DT and declining use of BTT [26]. This shift has been partly attributed to changes in the heart transplant allocation system that prioritise patients receiving temporary mechanical circulatory support over those supported with durable LVADs, thereby reducing the relative advantage of a BTT approach. This distinction is relevant because prognosis after LVAD implantation has been shown to vary according to indication. Contemporary real-world data report 2-year survival of approximately 78% among BTT patients compared with 71% in DT recipients; however, this difference likely reflects variations in baseline risk profiles and comorbidity burden rather than intrinsic differences in outcomes during LVAD support [28]. This interpretation is supported by our findings, as no significant difference in survival between BTT and DT patients was observed after adjustment for baseline characteristics and INTERMACS profiles. Moreover, because patients who underwent heart transplantation after clinical stabilisation were censored at the time of explantation, on-device survival estimates may have been influenced by informative censoring, particularly in the BTT group.

The adverse event profile in our cohort was consistent with that reported for modern centrifugal-flow LVAD therapy in the contemporary literature. Notably, we observed no pump thrombosis, mirroring the excellent haemocompatibility demonstrated with the HeartMate 3 in the MOMENTUM 3 trial, where thrombosis rates were approximately 1–2%, and substantially lower than historical second-generation devices [8]. Neurological events were also comparable: ischaemic stroke occurred in 12% of patients over a median 1.5-year follow-up, translating to an annualised risk of ~8%, broadly consistent with late INTERMACS estimates [29]. In contrast, bleeding remained the most frequent complication, affecting nearly half of patients overall, including 21% with gastrointestinal bleeding, consistent with INTERMACS and EUROMACS reports showing bleeding rates of approximately 12–18 events per 100 patient-years and gastrointestinal bleeding in up to one-third of recipients [30]. Infection rates in our cohort (50% device-specific and 21% device-related) likewise reflect the persistent infectious burden described in real-world registries

(≈3–4 events per 100 patient-months) [29]. Taken together, the contemporary complication spectrum has shifted towards bleeding and infection, and our real-world outcomes mirror this evolving pattern. It is also noteworthy that aspirin combined with vitamin K antagonist therapy was used as standard practice throughout most of the study period, a regimen that is a recognised contributor to the haemocompatibility-related bleeding that now dominates the adverse-event profile of contemporary LVAD therapy and that may have contributed to the observed bleeding burden. Following publication of the ARIES-HM3 trial, which demonstrated that aspirin removal may safely reduce haemorrhagic events without increasing thrombotic complications [21], aspirin was selectively discontinued on a case-by-case basis in selected patients according to individual haemorrhagic and thrombotic risk profiles. Precise quantification of antithrombotic regimens over the full follow-up period was not feasible given the dynamic and individualised nature of these adjustments in routine clinical practice. In addition, adjunctive approaches such as digoxin have been proposed to mitigate angiodysplasia-related gastrointestinal bleeding – a common mechanism in LVAD recipients – although supporting evidence remains limited and largely observational [31]. Finally, aortic insufficiency is a recognised complication of long-term LVAD support, resulting from the continuous unloading of the left ventricle and reduced aortic valve opening, which may lead to progressive valvular incompetence over time [32]. Although a systematic assessment of aortic insufficiency progression was not performed in the present study, this complication was monitored as part of routine echocardiographic surveillance. The clinical impact of aortic insufficiency in our cohort is difficult to quantify retrospectively; however, its management – ranging from conservative optimisation of LVAD speed to surgical or transcatheter valve intervention in selected cases – remains an important aspect of long-term LVAD care that warrants prospective evaluation.

Overall, our study suggests that excellent outcomes can be achieved outside very high-volume centres when care is delivered within a dedicated multidisciplinary framework.

Several limitations merit consideration. This was a single-centre observational study with a modest sample size, and subgroup analyses were exploratory and likely underpowered to detect moderate differences between LVAD indications (BTT or DT). The small number of patients remaining at risk beyond 4–5 years, particularly in the BTT group, limits the precision of late Kaplan–Meier estimates and warrants cautious interpretation of survival differences between groups at these time points. As with any non-randomised design, residual confounding cannot be excluded despite multivariable adjustment. In addition, practice patterns, patient selection and perioperative management evolved over the long study period; in particular, antithrombotic strategy was individualised and was not quantified at the patient level over follow-up, so the observed bleeding burden cannot be attributed to a specific antithrombotic regimen, and the impact of aspirin withdrawal in some patients after the ARIES-HM3 trial could not be formally assessed. Some potentially relevant variables were not collected, including patient-reported outcomes and quality-of-life measures, limiting a more comprehensive assessment of functional status and patient-centred benefits. Because a substantial proportion of patients underwent heart transplantation, which was treated as a censoring event, Kaplan–Meier estimates may overestimate event incidence by treating transplantation as non-informative rather than as a competing risk. Reassuringly, our pre-specified sensitivity analysis treating transplantation as a non-censoring event yielded consistent survival estimates, mitigating this concern. Finally, although consecutive inclusion enhances real-world relevance, results from a specialised tertiary centre may not be fully generalisable to other settings. Nevertheless, the comprehensive follow-up and the inclusion of unselected patients provide a pragmatic and externally valid view of contemporary LVAD outcomes.

Conclusions

In this contemporary real-world cohort of 100 consecutive patients, HeartMate 3 LVAD therapy provided durable long-term support, with a 1-year and 5-year survival on device support of 85% and 64%, respectively. Adverse event rates were broadly consistent with those reported in contemporary registries, demonstrating that outcomes consistent with those of large-scale programmes can be achieved in a low-volume tertiary centre.

Data sharing statement

Deidentified individual participant data underlying the results reported in this article, including a data dictionary, may be made available upon reasonable request to the corresponding author (HL). Data will be shared with qualified researchers for purposes of replication or secondary analyses,

subject to approval by the local ethics committee (CER-VD) and execution of a data sharing agreement. No additional related documents (e.g. analytical code, study protocol) will be shared. Data will be available indefinitely following publication.

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Use of AI: The authors declare that no generative artificial intelligence (AI) tools or AI-assisted technologies were used in the drafting, writing or creation of this manuscript.

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Supplementary Table 1. Patients' baseline characteristics by LVAD indication (BTT vs. DT)

Parameters	**BTT (n=65)**	**DT (n=29)**	**P-value**
Age, years – mean (SD)	52.5 (10.1)	70.4 (5.3)	<0.001
Male sex – n (%)	59 (90.8)	23 (79.3)	0.12
HF Etiology – n (%)			0.044
- Ischemic etiology	48 (73.8)	17 (58.6)	
- Non-ischemic etiology	17 (26.2)	12 (41.4)	
BMI, kg/m^2 – mean (SD)	26.8 (5.3)	25.5 (3.8)	0.25
eGFR, ml/min/m^2 – mean (SD)	69.8 (26.0)	41.1 (15.8)	<0.001
CKD (eGFR <60 ml/min/m^2) – n (%)	23 (35.4)	25 (86.2)	<0.001
Atrial fibrillation/flutter on ECG – n (%)	11 (16.9)	4 (13.8)	
INTERMACS class – n (%)			0.21
- 1	12 (18.5)	1 (3.4)	
- 2	9 (13.8)	4 (13.8)	
- 3	19 (29.2)	8 (27.6)	
- 4/5	25 (38.5)	16 (55.2)	
NYHA – n (%)			0.20
- III	19 (29.2)	4 (13.8)	
- IV	46 (70.8)	25 (86.2)	
Diabetes – n (%)	20 (30.8)	8 (27.6)	0.76
Carotid disease – n (%)	1 (1.5)	3 (10.3)	0.05
SBP, mmHg – mean (SD)	98 (12)	104 (19)	0.09
MAP, mmHg – mean (SD)	76 (11)	79 (14)	0.31
Echocardiographic and hemodynamic data			
LVEF, % – mean (SD)	20.6 (6.9)	22.7 (6.0)	0.15
LVEDVi, mL/m^2 – mean (SD) (n=83)	114.7 (47.2)	107.4 (31.5)	0.48
LVESVi, mL/m^2 – mean (SD) (n=77)	92.2 (42.7)	82.3 (27.6)	0.31
Cardiac index, mL/min/m^2 – mean (SD)	2.2 (0.4)	2.1 (0.4)	0.43
mPAP, mmHg – mean (SD)	33.2 (9.8)	34.7 (9.5)	0.56
PCWP, mmHg – mean (SD)	24.2 (8.2)	22.6 (7.4)	0.43
PVR, Wood Units – mean (SD)	2.1 (0.9)	3.1 (1.3)	<0.001
Preimplantation support			
ICU – n (%)	28 (43.1)	6 (20.7)	0.037
Temporary MCS – n (%)			0.09
- ECLS	14 (21.5)	1 (3.4)	
- Impella 5.5	0 (0)	0 (0)	
- Berlin Heart EXCOR® device	2 (3.1)	0 (0)	
Dialysis – n (%)	9 (15.0)	7 (29.2)	0.14
Mechanical ventilation – n (%)	19 (29.2)	4 (13.8)	0.10

This analysis included 94 patients (6 categorized as other than BTT or DT).
Abbreviations: AF = atrial fibrillation; BMI = body mass index; BTT = bridge-to-transplant; CKD = chronic kidney disease; DT = destination therapy; ECG = electrocardiogram; ECLS = extracorporeal life support; eGFR = estimated glomerular filtration rate; HF = heart failure; ICU = intensive care unit; INTERMACS = Interagency Registry for Mechanically Assisted Circulatory Support; LVEDVi = left ventricular end-diastolic volume indexed to body surface area; LVEF = left ventricular ejection fraction; LVESVi = left ventricular end-systolic volume

indexed to body surface area; MAP = mean arterial pressure; MCS = mechanical circulatory support; mPAP = mean pulmonary arterial pressure; NYHA = New York Heart Association; PCWP = pulmonary capillary wedge pressure; PVR = pulmonary vascular resistance; SBP = systolic blood pressure.

Supplementary Table 2. Patients' perioperative procedures by LVAD indication (BTT vs. DT)

Parameters	**BTT (n=65)**	**DT (n=29)**	**P-value**
Median sternotomy – n (%)	57 (87.7)	26 (89.7)	0.45
Left thoracotomy – n (%)	6 (9.2)	1 (3.4)	
Double mini-thoracotomy – n (%)	2 (3.1)	2 (6.9)	
CPB time, min – mean (SD)	70.8 (22.9)	72.2 (21.1)	0.78
Aortic cross clamp – n (%)	4 (6.2)	1 (3.4)	0.59
Concomitant cardiac procedures			
- AV replacement – n (%)	3 (4.6)	1 (3.4)	0.80
- Perioperative ASD closure – n (%)	7 (10.8)	1 (3.4)	0.24

This analysis included 94 patients (6 categorized as other than BTT or DT).
Abbreviations: ASD = atrial septal defect; AV = aortic valve; BTT = bridge-to-transplant; CPB = cardiopulmonary bypass; DT = destination therapy.

Supplementary Table 3. Causes of death on LVAD support (n=27)

Cause of death	Number of deaths	% of total deaths
Cardiovascular / device-related	**9**	**33%**
Cardiac arrest (PEA / VF / VT)	3	11%
Right ventricular failure	2	7%
Acute pulmonary edema / atrial fibrillation	1	4%
Iatrogenic pulmonary artery injury	1	4%
Primary graft dysfunction	1	4%
Traumatic brain injury	1	4%
Neurological	**3**	**11%**
Ischemic stroke	3	11%
Infectious / sepsis	**3**	**11%**
LVAD-specific infection (Pseudomonas aeruginosa)	1	4%
Fungal sepsis	1	4%
Aspiration pneumonia	1	4%
Multi-organ failure	**2**	**7%**
Non-cardiovascular comorbidities	**4**	**15%**
Metastatic cancer	1	4%
Traumatic fall / hip fracture	1	4%
SARS-CoV-2 / COVID-19	2	7%
Withdrawal of life-sustaining therapy	**5**	**19%**
Total	**27**	**100%**

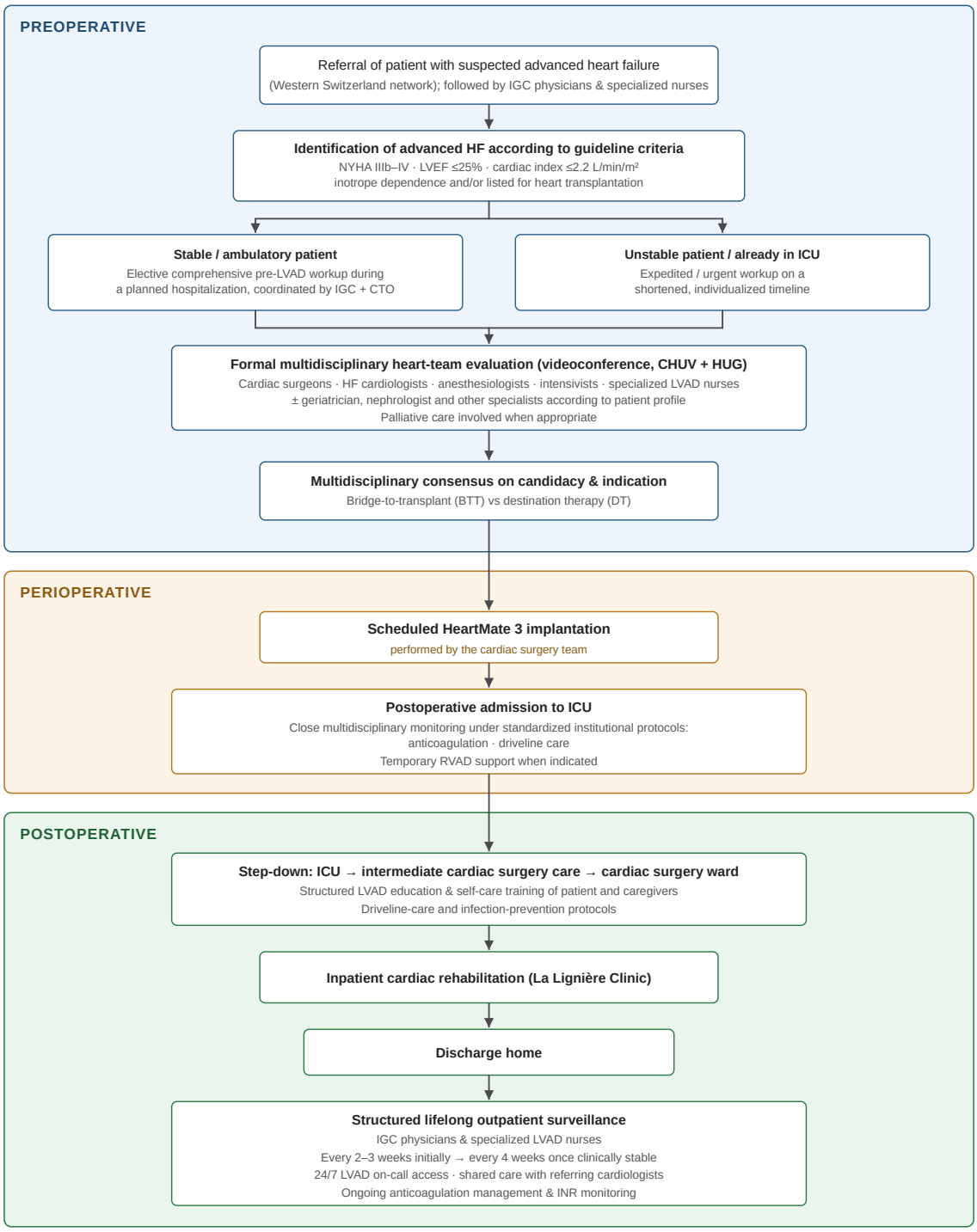
Abbreviations: LVAD = left ventricular assist device; PEA = pulseless electrical activity ; VF = ventricular fibrillation; VT = ventricular tachycardia; SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2.

Supplementary Table 4. Patients' postoperative outcomes and adverse events

Parameters	BTT (n=65)	DT (n=29)	P-value
Hemodynamic support			
Right ventricular failure – n (%)	19 (29.2)	16 (55.2)	0.016
Temporary RVAD requirement – n (%)	13 (20.0)	11 (37.9)	0.07
Length of RVAD support, days – mean (SD)	6.7 (0.8)	8.4 (0.7)	0.15
Hemocompatibility-related adverse events			
Pump thrombosis – n (%)	0 (0.0)	0 (0.0)	NA
Overall bleeding events – n (%)	25 (38.5)	18 (62.1)	0.046
Major bleeding – n (%)	18 (27.7)	11 (37.9)	0.34
GI bleeding – n (%)	8 (12.3)	11 (37.9)	0.005
Infectious complications			
LVAD-specific infection – n (%)	31 (47.7)	17 (58.6)	0.40
LVAD-related infection – n (%)	13 (20.0)	6 (20.7)	0.95
Neurological events			
Ischemic stroke – n (%)	6 (9.2)	5 (17.2)	0.23
Hemorrhagic stroke – n (%)	0 (0.0)	2 (6.9)	0.034
Renal complications			
AKI requiring dialysis – n (%)	9 (13.8)	8 (27.6)	0.14
Length of stay			
ICU LOS, days – median [IQR]	8 [5-19]	11 [7-36]	0.13
Overall LOS, days – median [IQR]	29 [24-63]	41 [27-88]	0.06

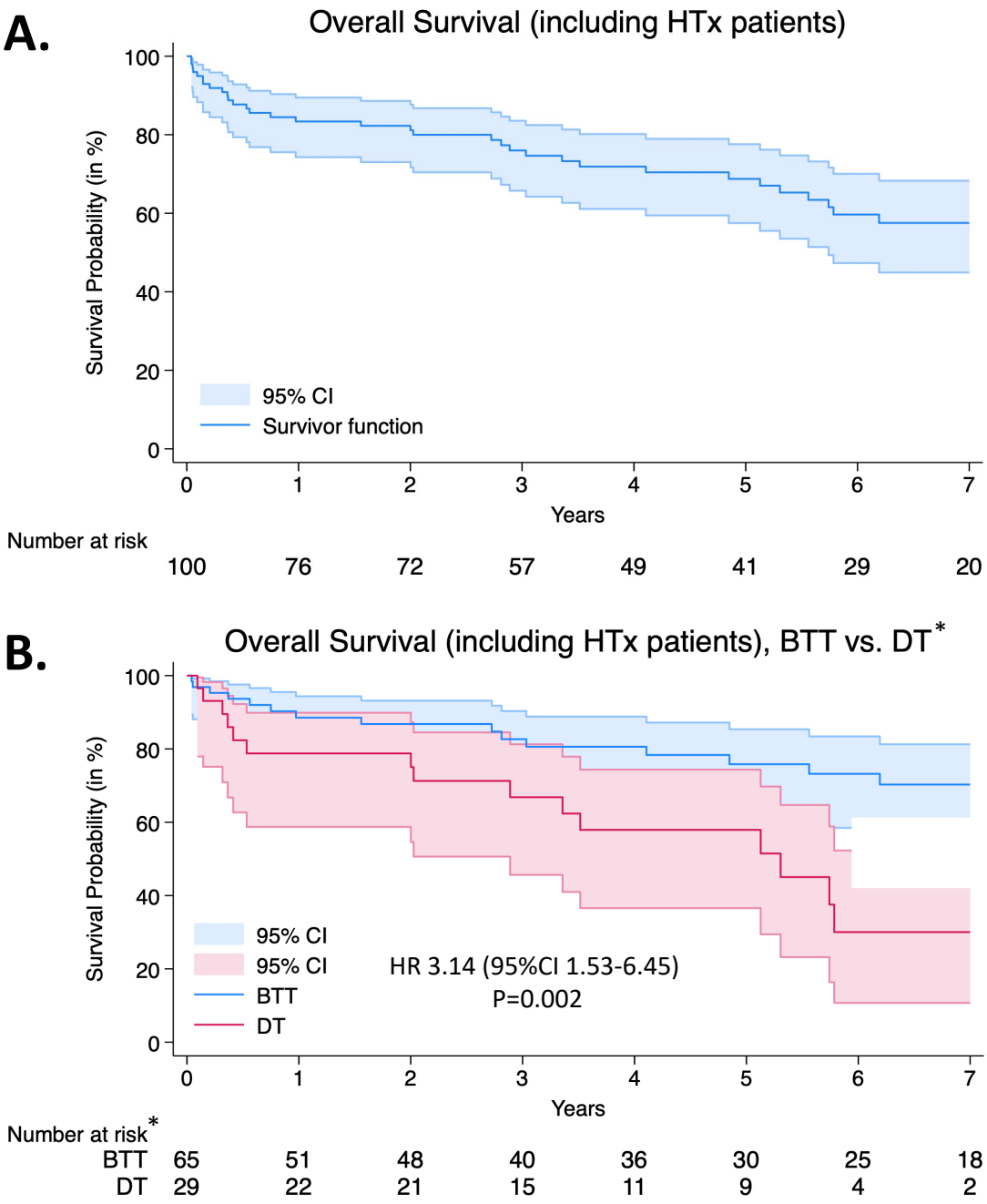
This analysis included 94 patients (6 categorized as other than BTT or DT).
Abbreviations: AKI = acute kidney injury; BTT = bridge-to-transplant; DT = destination therapy; GI = gastrointestinal; ICU = intensive care unit; LOS = length of stay; LVAD = left ventricular assist device; RVAD = right ventricular assist device.

Supplementary Figure 1. Institutional organization and patient care pathway for HeartMate 3 LVAD therapy at Lausanne University Hospital



The figure summarizes the preoperative evaluation and multidisciplinary decision process, the perioperative course, and the postoperative in-hospital and long-term outpatient follow-up pathway.
Abbreviations: CTO = organ transplant coordination; HF = heart failure; HUG = Geneva University Hospitals; ICU = intensive care unit; IGC = advanced heart failure unit; LVAD = left ventricular assist device; NYHA = New York Heart Association; RVAD = right ventricular assist device.

Supplementary Figure 2. Overall survival (including heart transplantation), (A) Overall cohort, (B) According to indication (destination therapy vs bridge-to-transplant), Lausanne University Hospital



*94 patients included (6 categorized as other than BTT or DT).
Abbreviations: BTT = bridge-to-transplant; DT = destination therapy; HTx = heart transplant; LVAD = left ventricular assist device.