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NONPHARMACOLOGIC THERAPY: SURGERY, VENTRICULAR ASSIST DEVICES, BIVENTRICULAR PACING, AND EXERCISE (A HASAN, SECTION EDITOR)

Current Review of Implantable Cardioverter Defibrillator Use in Patients With Left Ventricular Assist Device

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Abstract

Purpose of Review While use of implantable cardioverter defibrillator (ICD) in patients with heart failure (HF) and reduced ejection fraction is recommended, their role in patients with left ventricular assist device (LVAD) remains controversial, especially with continuous flow (CF) devices.

Recent Findings Ventricular arrhythmias (VA) in LVAD patients are frequent and associated with worse outcomes, especially postoperatively. Data on the role of ICDs in LVAD patients are scarce, based on case reports or small retrospective series. While the majority of LVAD patients currently have an ICD, it seems that some might not derive any benefit, with additional risks in terms of inappropriate shocks, psychological distress, and infections.

Summary Some CF-LVAD patients are at high risk of VA and hemodynamic collapse; under those circumstances, an ICD might provide benefits. A randomized-controlled trial of routine ICD implantation in CF-LVAD would be needed to clarify their impact on survival in low risk patients.

Keywords Implantable cardioverter defibrillator · Left ventricular assist device · Heart failure · Arrhythmias

Abbreviations

ACEI	Angiotensin converting enzyme inhibitor
AF	Atrial fibrillation
ATP	Anti-tachycardia pacing
BNP	Brain natriuretic peptide
BTT	Bridge to transplantation
CF	Continuous flow
CRT	Cardiac resynchronization therapy
HF	Heart failure
HFrEF	Heart failure with reduced ejection fraction
HVAD	HeartWare ventricular assist device
ICD	Implantable cardioverter defibrillator
INTERMACS	Interagency Registry for Mechanically Assisted Circulatory Support
LBBB	Left bundle branch block
LVAD	Left ventricular assist device
MCS	Mechanical circulatory support
NYHA	New York Heart Association
PF	Pulsatile flow
QALY	Quality-adjusted life-years
RV	Right ventricle
SCD	Sudden cardiac death
S-ICD	Subcutaneous implantable cardioverter defibrillator
TV-ICD	Transvenous implantable cardioverter defibrillator
UNOS	United Network for Organ Sharing

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Topical Collection on *Nonpharmacologic Therapy: Surgery, Ventricular Assist Devices, Biventricular Pacing, and Exercise*

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VA	Ventricular arrhythmias
VF	Ventricular fibrillation
VT	Ventricular tachycardia
WCD	Wearable Cardioverter Defibrillator

Introduction

Heart failure (HF) is the fastest growing cardiovascular condition in the last decades, owing to aging of the population and advances in pharmacological and device therapies [1]. It is the first cause of hospital admission after age 65 and is associated with high mortality, morbidity, and substantial healthcare costs [2, 3]. While overall mortality increases with disease severity, the cause of death is influenced by symptoms severity, with New York Heart Association (NYHA) functional class I–III patients dying more frequently from sudden cardiac death (SCD), usually due to ventricular arrhythmia (VA), and NYHA functional class IV patients succumbing to progressive pump failure [4, 5]. This finding constitutes the basis for current guidelines, with class I recommendations for implantable cardioverter defibrillator (ICD) implantation for primary prevention of SCD in patients with HF with reduced ejection fraction (HFrEF) on optimal medical therapy. On the other hand, ICDs are not indicated for refractory NYHA class IV patients, who are not candidates for cardiac transplantation, left ventricular assist device (LVAD), or cardiac resynchronization therapy (CRT) (class of recommendation III, level of evidence C) [6].

The use of durable mechanical circulatory support in highly selected patients with advanced HF and refractory symptoms has significantly improved survival and quality of life, even in patients not eligible for cardiac transplantation [7–9]. Current generation of continuous flow (CF)-LVAD provides adequate cardiac output, making circulatory collapse and syncopal events rare in the presence of sustained VA, even ventricular fibrillation (VF) [10]. However, complications such as progressive right ventricular (RV) failure can occur and thrombus formation due to tachyarrhythmia-induced myocardial standstill may lead to embolization or pump thrombosis. In addition, ICDs are associated with incremental costs, increased risk of bleeding, and potential infection of both devices [11–13]; the latter risk may be potentially alleviated by the use of subcutaneous ICDs (S-ICD). Ventricular arrhythmias in LVAD patients are frequently encountered, but whether an ICD provides a survival advantage or any additional benefits remains controversial [6, 10]. Nevertheless, international guidelines recommend that in *patients who have an ICD prior to mechanical circulatory support (MCS), the ICD should be reactivated in the postoperative setting* (class I, level of evidence A), and *routine placement of an ICD should be considered for patients who did not have an ICD prior to MCS* (class I, Level of evidence B) [14]. These recommendations are based on small retrospective studies and case reports, in the absence of randomized-controlled trial [15, 16]. Therefore, we aim to review the evidence regarding VAs occurring in LVAD patients. Our objectives are threefold (1): review the mechanisms of VA in patients with LVAD (2); evaluate the consequences of VAs in patients with LVAD; and (3) provide some insight regarding the choice of device to implant in LVAD patients—S-ICD or transvenous (TV-ICD). We herein hope to provide some guidance for decision-making in advanced HF patients.

Predisposing Factors for VA in LVAD Patients

The most important predictive risk factor for VA in the LVAD population is a history of VA prior to implantation [17]. The presence of an anatomical scar substrate seems more important than the etiology of HF itself, with some reports showing a 2.3-fold increase risk of VA in non-ischemic cardiomyopathy [18, 19], while others suggest an ischemic etiology as being predictor of VA [20]. Increased filling pressure, depicted by brain natriuretic peptide (BNP) serum levels greater than 1500 pg/mL, is an independent predictor of SCD and increased VA burden [21–24]. Also, an increased incidence of VA has been demonstrated with CF-LVAD compared with pulsatile (PF) pumps [25]. Other factors such as advanced age, increased body surface area, longer QT interval, electrolyte disturbances, the absence of beta-blocker, and a history of atrial fibrillation have all been associated with increased risk of VA [26–28].

Prevalence and Mechanisms of VA in LVAD Patients

The reported prevalence of early (within 30 days) and late VA after LVAD implantation varies depending on patient population, type of LVAD (PF versus CF), definition of the arrhythmia, study design, and duration of follow-up [25].

Mechanisms of Early VA

Early VA are found in more than one third of patients within 30 days after LVAD implantation. They carry a poor prognosis, especially with PF-LVAD, with a mortality as high as 54% when occurring within the first week, compared with 9% in patients not experiencing VA [20, 29]. Nevertheless, the absence of VA in the early postoperative period does not preclude later arrhythmic events, but the risk decreases over time [18].

The period after any type of cardiac surgery is one of great physiological instability, due to the systemic inflammatory syndrome, electrolyte imbalances, QT prolongation and/or

acute repolarization abnormalities, inotropic stimulation, infection, and/or ischemic events. In addition, factors specifically related to the LVAD, such as physiological adaptation to continuous flow, myocardial irritation from the inflow cannula, scarring of the apical wedge, suction events, and mechanoelectrical feedback may further contribute to enhance this arrhythmogenic vulnerability [30–34, 35•, 36•]. Suction events may cause early or late VA when pump unloading exceeds the left ventricular (LV) preload, like with severe volume depletion or with high pump speed; the LV might collapse or its walls might come into contact with the inflow cannula, potentially triggering ventricular tachycardia (VT) [7, 36•].

Mechanisms of Late VA

Late VA are usually caused by scar tissue, either form the apical wedge around the inflow cannula, or from preexisting fibrosis favoring reentrant circuits [35•]. Myocardial structural changes induced by the device and alterations in ion channel gene expression [25] modify myocardial electrophysiological properties and may further increase its vulnerability to VA [36•]. Moreover, in HF patients, atrial fibrillation (AF) increases myocardial susceptibility to VA, especially after LVAD implantation [27]. Galand and colleagues recently identified 6 independent predictors of late VA in 494 patients (1): the presence of VA or (2) AF prior to LVAD implantation (3); VA < 30 days postoperatively (4); non-ischemic cardiomyopathy (5); delay > 12 months between the diagnosis of HF and LVAD implantation; and (6) the absence of angiotensin converting enzyme inhibitor (ACEI) therapy post LVAD [37].

Consequences of VA in LVAD Patients

First-generation PF-LVAD were very sensitive to arrhythmia-induced fall in cardiac output, which increased mortality in bridge-to-transplant (BTT) patients (33% versus 18% in the absence of VA) over a mean support duration of 93 days [20]. On the other hand, CF devices are able to maintain cardiac output, and VA are frequently asymptomatic, sometimes revealed only at the time of ICD interrogation [38•]. Even rapid VT or VF can be well-tolerated for prolonged periods of time [39, 40•]. Kociol and colleagues have suggested that the non-supported right ventricle (RV) during VA adopts a Fontan-like physiology to explain this absence of circulatory collapse despite VA/VF with CF-LVAD: the non-contracting RV leads to an underfilled LV and reduced cardiac output, but without hemodynamic compromise. Consequently, factors decreasing hemodynamic tolerability include elevated pulmonary pressures and vascular resistance as well as low central venous pressure [41]. Nevertheless, VA occurring in CF-LVAD patients may lead to serious complications, such as low output states, progressive RV failure, venous congestion (peripheral, renal, hepatic, and pulmonary), and thrombus formation leading to embolization and pump thrombosis [11–13]. Those complications harbor serious consequences with significant impacts on survival and quality of life and need to be better addressed [35•].

Impact of ICD in CF-LVAD Patients

The influence of simultaneous ICD and LVAD implantation on survival remains controversial [42]; current state of knowledge is summarized in Table 1. While some studies suggest improved survival in patients with PF-LVAD, the benefit of ICD in patients with CF-LVAD is less clear [38•, 41, 43, 46•, 50, 51]. In 2017, three analysis on BTT population from the Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) and United Network for Organ Sharing (UNOS) registries (2006 to 2016, 2004 to 2014, and 2008 to 2015) looked at the impact of ICD in CF-LVAD patients using propensity score matching and did not find any survival benefit [29, 48, 49]. Importantly, these observational findings as well as the use of propensity score matching may not account for multiple unmeasurable confounders and competing risks for the primary time-to-event of interest [52]. In addition, data on RV function and pulmonary vascular resistance and pressures were not available [48, 49]. Finally, as much as 80% of patients of the initial cohorts have been discarded for the purpose of propensity matching, mainly those at high risk of VA [48], such as critically ill patients and those unable to be discharged from the hospital, creating an important selection bias toward "healthier" patients, potentially masking the survival benefits of ICDs in the sicker ones. On the other hand, significant reduction in mortality with ICD has been shown in 94 LVAD patients followed for 13 months with half having a history of VA before LVAD implantation [46•].

To overcome the multiple biases from these retrospective analysis, Galand and colleagues recently analyzed 494 patients from 19 centers and suggested a "VT-LVAD score", based on the 6 independent predictive factors previously discussed: VAs prior to LVAD implantation (2 points); no ACEI post LVAD (2 points); HF duration > 12 months (2 points); VA post implantation < 30 days (2 points); AF prior to LVAD (1 point), and idiopathic dilated cardiomyopathy (1 point) [37]. They proposed 4 groups based on long-term arrhythmic risk (low, intermediate, high, and very high), with increasing prevalence of VA at 1-year (0%, 8%, 31%,, and 55%, respectively); this score could be a useful decision tool regarding ICD for low risk patients, to avoid the inherent risk of ICD implantation in the small subset of patients who do not seem to derive benefit from ICDs.

Table 1 Published studies of ICD in LVAD patients

Author-year publication	Study period	Dataset	Patients	BTT (%)	Follow-up (median or mean)	Incidence of VAs post LVAD	Mortality (ICD versus no ICD)	Other endpoints
Andersen 2009 [43]	2006–2008	Single center (Rigshospitalet, Copenhagen)	$N = 23$ ICD 74% CF-LVAD 100%	NA	Median ICD 214 months no ICD 52 months	52% (75% within 4 weeks of LVAD)	No difference	3 symptomatic; 1 RV failure before the episode of sustained VA
Cantillon 2010 [44]	1991–2008	Single center (Cleveland Clinic)	$N = 478$ ICD 18.8% LVAD 86.6% RVAD7.5% BIVAD 5.9% PF-LVAD 74.1% CF-LVAD 8.2% extracorporeal 10.5%	NA	Median 56 days	28.9% of patients with an ICD	ICD 24.4% No ICD 36.9% $p = 0.026$ ICD had lower mortality (propensity matched analysis) OR 0.42 95% CI 0.19–0.95	Sustained VAs in 32% of the cardiovascular deaths in patients without an ICD
Oswald 2010 [30]	2005–2008	Single center (Hannover Medical School)	$N = 61$ ICD 100% CF-LVAD 100%	NA	Mean 365 ± 321 days	34% received appropriate ICD intervention (VA)	NA	Inappropriate ICD intervention in 25%
Refaat 2012 [16]	1996–2003	Single center (University of Pittsburgh Medical Center)	$N = 144$ ICD 31% PF-LVAD 85 PF-BIVAD 59	NA	Mean 119 days	NA	1 year survival to transplantation ICD 91% No ICD 57% $p = 0.01$	ICD had increased survival by multivariate analysis OR 2.72 95% CI 1.03–7.16
Brenyo 2012 [45]	2006–2010	Single center (University of Rochester Medical Center)	$N = 61$ ICD 100% CF-LVAD 100%	72	Mean 1.8 years	31% (events during hospitalization for LVAD implantation excluded)	NA	Increased risk of death with VAs HR 13.92
Raasch 2012 [10]	2006–2011	Single center (University of North Carolina)	$N = 61$ ICD 80% CF-LVAD 100%	44	All implant followed until August 2011	43% (65% during hospitalization and 35% after discharge)	NA	Patients with VAs had more hospitalizations, greater anti-arrhythmic drugs use, frequently requiring defibrillation
Garan 2013 [46]	2012	Single center (Columbia University Medical Center)	$N = 94$ ICD 82% CF-LVAD 100%	48.9	Mean ICD 969.1 pt-months No ICD 276.2 patient-months	20.2% (early); 23.4% (> 30 days after implant)	No difference ICD 90.6% No ICD 85,6% $p = 0.55$ (early VA exclude)	1 death due to intractable VT leading to RV failure (ICD group)

Table 1 (continued)

Author-year publication	Study period	Dataset	Patients	BTT (%)	Follow-up (median or mean)	Incidence of VAs post LVAD	Mortality (ICD versus no ICD)	Other endpoints
Enriquez 2013 [28]	2008–2012	Single center (Mount Sinai Medical Center)	*N* = 106 ICD 78.3% CF-LVAD 100%	87.7	Mean 254 ± 194 days	34.9% early 67,6% > 30 days: 51.4%	No difference HR1.12 95% CI 0.37–2.25	15.9% of the VA episodes were unstable
Lee 2015 [47]	2004–2013	Single center (St. Vincent's Hospital Sydney)	*N* = 100 ICD 64% CF-LVAD 100%	90	Mean 364 ± 295 days	83%	Decreased mortality in the ICD group HR 0.36 95% CI 0.13–0.86 (p = 0.02)	Greatest benefit < 90 days of implant HR 0.19 95% CI 0.05–0.58 (p = 0.005) No mortality benefit beyond year (small #) HR: 0.81 95% CI 0.38–1.39 (p = 0.56)
Younes 2017 [29]	2008–2015	UNOS *N* = 3626 Propensity score-matched	*N* = 1444 ICD 50% CF-LVAD 100%	100	Median 5.6 months	NA	No difference in wait-list mortality HR 1.19 95% CI 0.75–1.88	2 arrhythmic deaths in ICD group and 5 in the no-ICD group
Clerkin 2017 [48]	2006–2016	INTERMACS *N* = 16,384 Propensity score-matched	*N* = 4418 ICD 50% CF-LVAD 100%	23.2	Median ICD 12.3 months No-ICD 12.5 months	ICD 21.9% No-ICD 22%	Increased 20% risk of death with ICD 95% CI 1.04–1.39	9% increased risk of death in the ICD group when analyzing the whole cohort (p = NS)
Clerkin 2017 [49]	2004–2014	UNOS *N* = 2990 Propensity score-matched	*N* = 1012 ICD 50% CF-LVAD 100%	100	Median ICD 287.5 versus No-ICD 305.5 days	NA	No difference HR 1.2 95% CI 0.66–2.17	No mortality difference for the full cohort HR 1.24 95% CI 0.89–1.71
Kutifuya 2019 [42]	2008–2014	Single center (University of Rochester Medical Center)	*N* = 191 ICD 67% CF-LVAD:\ 100%	NA	Mean 766.5 ± 365 days	NA	No difference HR 0.64 95% CI 0.23–1.76	No difference after adjustment for age, diabetes, gender, and INTERMACS level 1

ICD Adverse Events in CF-LVAD Patients

ICDs may be associated with important complications both at implantation (bleeding, pneumothorax, hemothorax, hematoma, pericardial effusion, or tamponade) and during long-term follow-up (lead dislodgment or malfunction, device malfunction, and thrombotic events), with potential deleterious effects of shocks (whether appropriate or not) on both myocardial function and psychological health [35•, 53]. In an observational cohort study of HF patients, a rate of 6.1 ICD-related complications per 100 patient-years requiring hospitalization or reoperation has been reported on a mean follow-up of 2.7 years [54]. In addition, both ICDs and LVADs may become infected, either locally (driveline or pocket) or through the bloodstream, necessitating re-intervention(s) [55]. Moreover, ICD-associated infections may disseminate to the pump and/or cannulas, requiring chronic suppressive antibiotic therapy, urgent transplantation, and/or LVAD exchange; the latter is not a benign procedure, with a reported 29.4% one-year mortality after exchange (11.8% for infection) [56]. Finally, the costs associated with prophylactic ICD implantation are high, with an incremental cost per quality-adjusted life-years (QALY) gained in the USA of $201,103, compared with a "no ICD strategy", in BTT-LVAD patients [57]. Consequently, routine prophylactic ICD implantation in CF-LVAD patients remains controversial despite being adopted by many centers worldwide [58].

ICD Programming in LVAD Patients

Given the hemodynamic stability of LVAD patients facing VA and to avoid the potential consequences of repeated shocks, a more "liberal" programming approach has been suggested with higher and longer VA detection intervals, and more aggressive anti-tachycardia pacing (ATP) [25, 35•]. This appealing strategy targets only sustained VA at risk of circulatory collapse [35•]. Unfortunately, a recent single center report showed no difference in the number of ICD shocks, time to first shock, and hospitalization for arrhythmic events or HF, when compared with standard programming in LVAD patients [59]. Further studies are required to determine the most appropriate ICD settings in this population of patients.

CRT in LVAD Patients

CRT improves mortality, morbidity, and remodeling in HF patients with underlying wide QRS [60]. Accordingly, a third of patients already have a CRT device in place at the time of LVAD implantation [61]. The benefits of reactivating the CRT after surgery remain unclear, as resynchronization could be difficult to achieve given the LVAD physiology and the absence of isovolumetric contraction and relaxation periods [62]. While some suggest CRT may be helpful for myocardial recovery [63], Tehrani and colleagues have shown no hemodynamic or echocardiographic benefit despite adequate biventricular pacing (> 95%) [62]. Moreover, CRT-on did not decrease mortality, re-hospitalization, VA incidence, and ICD therapies compared with CRT-off [62, 63]. Potential explanations include the following: (1) a pro-arrhythmic effect of the LV lead, especially at the time of implantation (2); a potential adverse hemodynamics effect of biventricular pacing on the LV in some patients with an underlying left bundle branch block (LBBB), where the abnormal septal motion may prevent dynamic obstruction of the inflow cannula, suction events, and likely provides some support to the RV (3); CRT may be overshadowed by the greater impact of the LVAD [62].

Choosing a Defibrillator: S-ICD, TV-ICD or Wearable Cardioverter Defibrillator?

The S-ICD has been developed to decrease complications associated with transvenous access, namely thrombosis, lead fracture, and infection [64]. Propensity-matched studies showed similar safety and efficacy for TV-ICD and S-ICD [65, 66], and two randomized studies (PRAETORIAN [67] and ATLAS [68]) are ongoing in HF patients. Issues with sensing, lead impedance, pacing threshold, and LVAD-associated electrical artifacts causing inappropriate shock delivery have been reported with TV-ICD, requiring lead revision and ICD testing in several instances [69, 70•, 71, 72]. Early reports suggest that S-ICD could be an interesting alternative to TV-ICD for patients awaiting transplantation or patients on LVAD [73, 74]. Devices' interaction between ICDs and LVAD are different depending on the type of ICDs: S-ICDs can record noises from the LVAD pump (located in front of the S-ICD device), while TV-ICDs have more interferences due to the inherent frequency of the LVAD [73, 75]. To decrease pump "noise" on 3 S-ICD vectors, it has been recommended to use the alternate vector. Recent reports of S-ICDs with different LVAD technologies (Jarvik 2000, HeartMate II, HeartMate III, and HVAD) have shown efficient termination of VA, without any evidence of mechanical interferences (i.e., inappropriate shocks) [73–77]. Specifically, there was no S-ICD-associated infection although inappropriate shocks due to unusual P wave over-sensing, with persistent interference with ICD telemetry (in all 3 vectors including alternate), have been reported in one patient, necessitating to change the S-ICD to TV-ICD [78]. A chest radiography and pictures of a patient combining LVAD and S-ICD are shown in Fig. 1.

Another interesting option is the wearable cardioverter defibrillator (WCD), which has been reported in 23 LVAD patients in the USA [79]. It seems to be a feasible alternative to monitor sustained VA, provide appropriate therapies, and withhold unnecessary shocks by using the response button

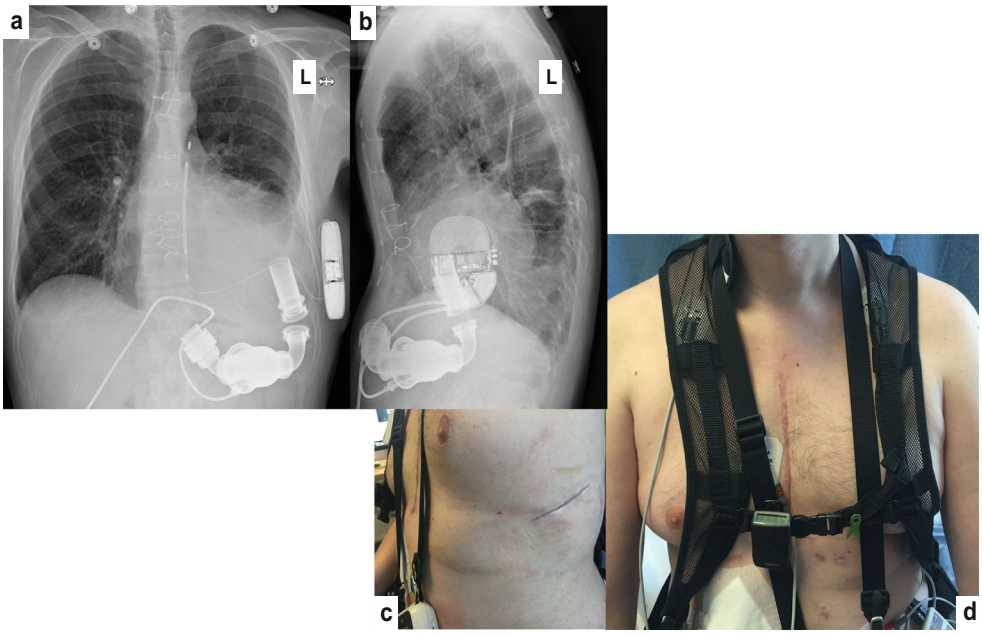

Fig. 1 Example of a 33 year-old patient with non-ischemic dilated cardiomyopathy and a LVEF of 20%. LVAD and S-ICD were implanted at the time of diagnostic in an INTERMACS 3 patient presenting with de novo heart failure. Chest radiography showing the LVAD (Heart Mate II) and S-ICD (Box and lead) in the posterior-anterior (**a**) and lateral (**b**) views. Pictures of the patient from face (**c**) and side (**d**)

for well-tolerated VA (4 episodes of VA reported, therapies withhold by the patient in 2 cases). No noise or interference has been reported between LVAD and WCD. However, observance and compliance to the WCD remain the cornerstone of that technology—patients being protected only if they do wear the device.

Although these alternatives to TV-ICD seem attractive, some restrictions limit their widespread use in the LVAD population. First, when patients need pacing and/or anti-tachycardia pacing (ATP) for slow VT termination, TV-ICD should be preferred. Second, the S-ICD VT detection zone cannot go below 170 bpm, potentially missing slower VTs, which are not uncommon in presence of amiodarone [80]. Moreover, special attention should be given to the RV function and pulmonary hemodynamics, given the potentially deleterious effect of VA on RV function; unnoticed or untreated sustained VTs could lead to hemodynamic compromise in a subset of LVAD patients which may be prevented with ATP.

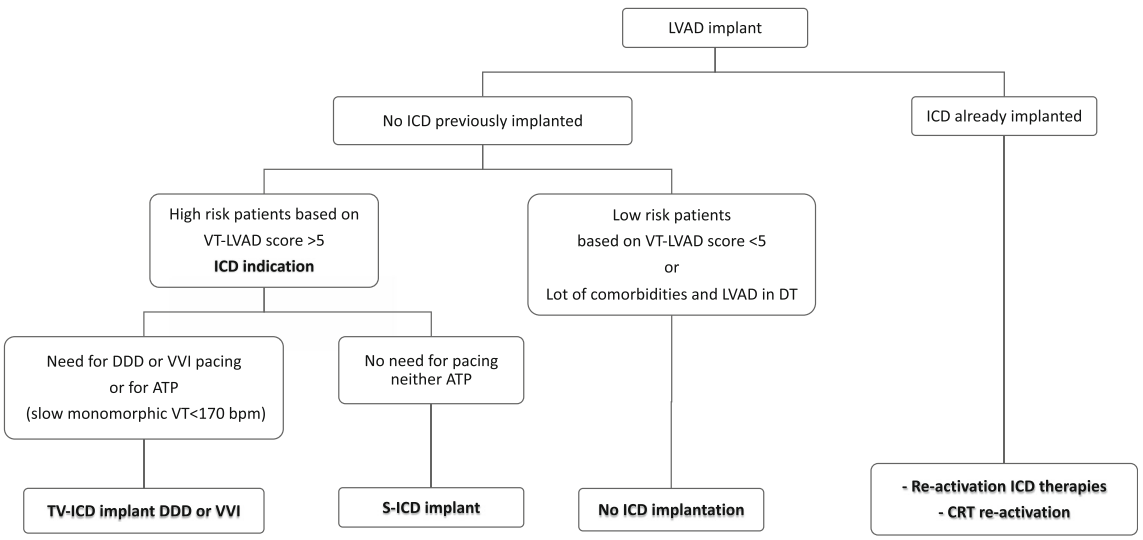

Fig. 2 Suggested algorithm for decision-making regarding ICD implantation in LVAD patients, based on whether an ICD has already been implanted or not, the need for pacing and/or ATP, and results of the VT-LVAD score (VAs prior to LVAD implantation (2 points), no ACEI post LVAD (2 points), HF duration > 12 months (2 points), VA post implantation < 30 days (2 points), AF prior to LVAD (1 point), idiopathic dilated cardiomyopathy (1 point))] [36•]. ACEI angiotensin converting enzyme inhibitor, ATP anti-tachycardia pacing, AF atrial fibrillation, CRT cardiac resynchronization therapy, DDD dual chamber pacemaker/defibrillator, DT destination therapy, HF heart failure, ICD implantable cardioverter defibrillator, LVAD left ventricular assist device, S-ICD subcutaneous ICD, TV-ICD transvenous ICD, VA ventricular arrhythmias, VVI ventricular pacemaker/defibrillator

Lastly, the S-ICD also has the potential to induce myocardial injuries and psychological distress secondary to shocks, which could be avoided with effective ATP. Nevertheless, new technologies are being developed with an upcoming leadless pacemaker communicating with the S-ICD; this combination will allow ATP as well as VVI back-up pacing, which can prove particularly useful in monomorphic VT to avoid some shocks, without the risks associated with transvenous devices [81, 82]. In addition, the greater cost of the S-ICD unit (total cost of $17,243 ± 2444 US versus $13,639 ± 6173 for the TV-ICD) might be offset over a longer follow-up time by its potentially lower complication rate, thereby providing a cost-effectiveness advantage [83]. Nevertheless, battery duration is so far shorter for the S-ICD than its transvenous counterpart which could become an issue in terms of infection risks and costs associated with battery replacement. Reducing potential complications is desirable in LVAD patients, especially in terms of infectious risk and venous access (considering the need for biopsies after transplantation), without compromising the appropriate therapies of VA [65, 66, 73].

Our Practice

In the absence of definitive data, the majority of advanced HF programs like ours still prophylactically implant an ICD or re-activated a previously implanted one in LVAD-supported patients [39]. In cases of previously implanted CRT, we usually re-activate both CRT and ICD therapies. However, in patients who did not receive an ICD before LVAD implantation, we elected to favor S-ICDs in the absence of pacing and/or ATP indications, while CRT may be exceptionally considered in presence of large LBBB. Unfortunately, WCDs are not available in Canada.

We are proposing a decision algorithm (Fig. 2) to guide clinicians in determining which patients would most benefit from ICD implantation, based on the VT-LVAD score [36•]. Arrhythmic risk assessment should be performed to decide whether to implant an ICD in LVAD patients, together with a heart team discussion.

Conclusion

Ventricular arrhythmias in LVAD patients are common and may harbor serious hemodynamic consequences, but the literature does not offer strong evidence to determine whether an ICD provides a survival benefit in patients implanted with CF-LVADs. Nevertheless, early termination of VA might be important in selected patients, more susceptible to develop hemodynamic compromise and RV failure during sustained VA. In addition, a S-ICD should be considered in the absence of pacing indications and/or ATP, as it seems safe in terms of device interactions and low risk of infection. Still, a heart team decision taking into account the patients' values and preferences is mandatory. There is an urgent need for more data addressing the usefulness of ICDs in CF-LVAD patients with low arrhythmic risk, including their potential complications.

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Compliance with Ethical Standards

Conflicts of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights This article does not contain any studies with human or animal subjects performed by any of the authors.

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