

REVIEW

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# Destination left ventricular assist devices in island states: asking too much or the inevitable solution

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## Abstract

**Background:** Destination left ventricular assist device placement is increasing as a result of donor shortages and changing patient attitudes. As organ shortages become critical, LVAD programs become fundamental even in more remote regions of the world including island states. Here, we provide a look into the current state and availability of LVAD programs in island states.

**Main body:** A narrative review was performed using the World Health Organization Global Index Medicus and PubMed/MEDLINE databases to identify articles describing the island states having reported LVAD placements and programs. Additionally, INTERMACS reports were used. Data were retrieved and a review is presented describing the current state of LVADs in island states. The Caribbean region as a whole has a heart failure (HF) prevalence of 814 per 100,000 and Oceania 667 per 100,000 people. We estimate that over 3000 people in these islands need either a heart transplant or an LVAD.

**Short conclusion:** For HF patients living in island regions, special attention should be paid to the inability of having access to specialized mainland medical care. The continuous quest for a solution to HF in island regions should include the establishing of high-quality LVAD programs in a transfer-network centralized/regionalized system to care for those patients not candidates for long-distance air-bridging.

**Keywords:** Island states, Left ventricular assist device, End-stage heart failure

## Background

Cardiovascular surgical care is undergoing important transformations resulting from technological advances in the form of minimally invasive, robotic surgery, circulatory support, and approaches to end-stage heart failure. Destination left ventricular assist device (LVAD) placement is increasing around the globe as a result of donor shortages and changing patient and caregiver attitudes, whether for personal, cultural, religious, or other reasons [1]. In the USA alone, over five million people live with

heart failure (HF) and over half a million are diagnosed every year [2, 3]. For advanced cases (NYHA stage IV), 1-year mortality has been reported to be as high as 75% [4]. Despite the success and standard of transplantation, up to 14.3% of patients die while on the waiting list [5]. By 2030, the cost of heart failure is expected to reach 70 billion dollars [2, 3]. In island states, there is an increased need for this technology due to the even lower rates of transplantation. The population of island states is approximately 65 million people across 58 islands regions [6, 7]. Of these, it is estimated that 540,150 people have or will soon be suffering from HF [2, 6–8]. Island states and regions such as the Caribbean have an upper-middle- or high-income profile (with the exception of islands such

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as the Dominican Republic and Haiti). However, population differences and healthcare policy disparities lead to consequences of limited access to quality and immediate cardiac surgical care [6–8]. The remote distances of island states from specialized mainland transplant centers make destination LVAD therapy an attractive solution [6–8]. In 2019, a record number of 3198 continuous flow LVADs were placed worldwide according to the INTERMACS database [1]. During the last decade (2010–2019), a total of 25,551 LVADs have been placed. Additionally, over 5000 heart transplants are being performed annually worldwide. As organ shortages become critical, patients keep dying waiting for a heart; LVADs have emerged as the only other viable option for many patients [1]. Here, we provide a look into the current state and availability of LVAD programs in island states across the world and insights into future care.

### Heart failure in island states

In low- and middle-income countries (LMICs) with similar demographic profiles such as those found in island regions, hospital admission rates due to heart failure have been reported to be 2.2% [3]. Global prevalence of HF remains high (831 per 100,000) and over 64 million people worldwide ail from HF [2]. The prevalence of HF in LMICs and high-income countries are 830 per 100,000 and 871 per 100,000 people, respectively [2]. The Caribbean region as a whole has a HF prevalence of 814 per 100,000 and Oceania 667 per 100,000 people [2]. In some countries, low organ donation rates of approximately 7 per million population are insufficient to meet the demands of the rise in HF care. Applying the ratio of heart transplant candidacy-to-population as seen in the USA to island states across the world (exclusively using population ratio), we estimate that over 3000 people in island states worldwide need either a heart transplant or an LVAD [5]. The income profile disparities between islands along with the healthcare burden of HF in island states remain a serious public health issue. In island states, special challenges exist. Aside from being remote distances from centralized and specialized mainland centers, emergency air-bridging may not always be a safe solution to patients with HF [8–10]. Despite the difficulties of being long distances from specialized centers many islands have managed to develop high-quality cardiac institutions overcoming the distance factor. These centers include but are not limited to *Health City Cayman Islands*, *ADK hospital Male Maldives*, *Eric Williams heart center in Trinidad and Tobago*, and *Martinique University Hospital Fort-de-France Martinique*. However, only *Grand Cayman* and *Singapore* have established LVAD programs. These centers have successfully developed quality cardiovascular care for especially

underserved regions of the world [6–8]. Despite these endeavors, the burden of HF makes ventricular assistance an underused and necessary solution to many of these islands.

Procedures such as aortic valve replacements or coronary artery bypass grafting are simpler than aspiring to develop heart failure programs including LVAD programs which require a more complex team and institutional infrastructure. Alongside the decreasing availability of cardiac transplant donors and recipients rejecting transplantation worldwide, the need to find alternative solutions to HF treatment is becoming critical. In centralized institutions in middle- to high-income countries, many programs have developed programs to answer to this shift from transplantation to destination LVAD. In LMICs and island states, however, these programs have faced a more challenging process. Technological advances regarding medical and surgical developments in island states reflect those of lower-middle-income countries.

### Cardiac surgery in island states

Of the 58 island states across the globe, over 40 cardiac surgical centers are spread across these islands, most of which are located in the Caribbean region [6–8]. Cardiac surgical care on islands is accomplished through three main systems: (1) local cardiac surgery, (2) visiting cardiac surgery teams, and (3) air-bridging patients to other neighboring institutions [6–11]. Despite these three systems, there is still a need for additional centers in both the Caribbean region and other island regions across the globe to answer to the cardiovascular surgical disease burden [6–11].

### Main text

A narrative review was performed using World Health Organization Global Index Medicus and PubMed/MEDLINE databases to identify articles describing the island states having reported LVAD placements and programs. Additionally, INTERMACS reports were used as supplementary sources. Data were retrieved and a review is presented describing the current state of LVADs in island states along with considerations for the need to develop LVAD programs.

### Results

#### Destination LVAD programs in island states

By the year 2030, a projected one in 33 adults will suffer from HF [1–3]. The discrepancy between those in need and those transplanted has translated into the fact that the number of patients treated with LVADs today, exceeds those treated with transplantation [12]. This technology is becoming so successful that over 150 centers in the USA have established LVAD destination

centers [12]. In 2014, the cardiovascular center Health City Cayman Islands on Grand Cayman became the first island in the Caribbean to perform an LVAD placement. The Centro Cardiovascular de Puerto Rico y del Caribe in San Juan, Puerto Rico, is currently in the process of developing an LVAD program. Other islands still depend on air-bridging for transplant and HF treatment. Singapore, having a population reaching six million, was the first island in the world (started in 2009) to develop a sustainable destination LVAD program [13]. Though Hawaii is not an island state but a US state, its development in cardiac surgery resembles that of island states. While heart transplantation in Hawaii began in 1987 at the St. Francis Medical Center in Honolulu, the average of three heart transplants per year corresponding to approximately 7 per 1,000,000 population led to a lack of federal funding [14]. Program funding eligibility requires a minimum of 10 transplants per year, which resulted in financial difficulties maintaining the program. Additionally, introducing an LVAD program requires centers to have a functioning transplant department. In their 2008 paper, Hong and colleagues expressed the unlikelihood of maintaining Hawaii’s transplant department [14]. Today, The Queen’s Medical Center in Honolulu is developing

an LVAD program. There are, therefore, two islands with financially supported and sustainable LVAD programs and another two underway (Table 1). With the exception of Grand Cayman, the population of Hawaii, Puerto Rico, and Singapore of >1,000,000, in addition to their high-income profile and healthcare policies, make a sustainable and quality LVAD program more feasible. Figure 1 shows islands performing/developing LVAD programs.

**Establishing destination LVAD programs**

Establishing an LVAD destination program requires first to determine the patient volume and need for this program. Hospital administrative support and investment is critical since an LVAD program increases hospital visibility but the financial compensation is delayed [12]. The core team should consist of the following: two cardiothoracic surgeons trained in LVAD implantation, one cardiologist experienced in HF management, perfusionists with knowledge in circulatory support, a cardiovascular anesthesiologist and intensivists with experience in HF, it is critical that those involved also be trained in extra-corporeal membrane oxygenation in case this becomes necessary. Additionally, an all-round cardiovascular support system is crucial, involving a nutritionist, psychologist,

**Table 1** Island states with LVAD programs

Island	Center	Year initiated	Population	Region
Singapore, Singapore	<i>National University Heart Centre</i>	2009	5,898,304	<i>Southeast Asia Sea</i>
Grand Cayman, Cayman Islands	<i>Health City Cayman Islands, Narayana Health</i>	2014	66,532	<i>Caribbean Sea</i>
Honolulu, Hawaii	<i>The Queen’s Medical Center</i>	In development	1,455,271	<i>Pacific Ocean</i>
San Juan, Puerto Rico	<i>Centro Cardiovascular de Puerto Rico y del Caribe</i>	In development	2,787,703	<i>Caribbean Sea</i>

LVAD left ventricular assist device



**Fig. 1** Islands performing/developing LVAD programs

rehabilitation expert, social workers, and nurses. Because of possible device malfunctions, there should be LVAD coordinators present [12]. An important element for maintaining a sustainable program is to establish partnerships with a nearby heart transplant center. This is critical for those patients who fall out of the “destination” profile and become “bridging” patients. Finally, patient selection is crucial since poor results will affect hospital expenditures and lead to unsustainable programs [12]. Highly specialized mainland centers such as in the Netherlands, have developed high-quality destination ventricular assisting programs and are moving away from the “transplant culture” and adopting a more mechanical support solution to HF. In 2014, at Leiden University Medical Center, Leiden, Netherlands, the first Dutch LVAD destination program reported their experience [15]. The Netherlands along with many other centers are experiencing a progressive and successful transition from transplantation to LVAD therapy.

As with heart transplantation, patients receiving LVADs as destination therapy on island states require careful and strict follow-ups. These consist of serial bloodwork, anti-coagulation monitoring, infection prevention, and thromboembolic/bleeding screening. Although dense, rigorous follow-up is critical for the success of these destination devices. Additionally, despite the superiority of transplantation to LVADs with regard to complications and infections, despite the risk of rejection, the decreasing pool of donors requires us to turn to this option.

## Discussion

### Impact of distance from an implant center

Because few island cardiac surgery centers have substantial experience with HF and heart transplant, most patients requiring transplants are air-bridged to mainland countries [6–11]. Despite this option many patients requiring transplantation often die waiting for a donor. Air-bridging systems and rapid ground transport teams are critical for the sustained support of island cardiac centers [6–11]. An example of islands at significant distances from mainland cardiac centers are the French Polynesian Islands which include Bora Bora and Tahiti. These South Pacific Ocean islands air-bridge cardiac surgical patients to either New Zealand (4100 km away) or Paris, France (15,700 km away) [16]. In a study by Gallandt and colleagues, an average residential distance of 44.2 miles from an LVAD implant center did not affect mortality, complications, nor quality of life following implant [17]. However, the need for air-bridging of patients from an island setting to mainland centers requires a different procedure and pathway from ground transport protocols [17]. In another study by Nelson and

colleagues, a more rural population and greater distance from the implant center was analyzed [18]. Residential distance of up to 120 miles from implant center did not increase mortality or complications [18]. These results strengthen the notion that well-established patient-to-center networking, following-up system, and transport protocols are crucial in maintaining a successful program even at remote distances [18]. Keeping in mind that preservation times more than 4-6 hours have been shown to impair cardiac graft function, long flight distances for rescue/implantation renders island patients at high risk [14]. However, newer technologies such as warm machine perfusion are gaining ground and will soon become a game changer in securing graft function during transfer offering additional options for island patients. In a commentary, Kilic proposed the solution of regionalizing/centralizing high-complexity cardiac care in island regions [9]. This is an ideal solution for island populations needing LVADs [9]. An example would be establishing an inter-island transfer-partnership network sending HF patients with indications for LVAD placements to the nearest experienced centers; Grand Cayman and Puerto Rico for Caribbean Sea patients, Singapore for Southeast Asia Sea patients, and Hawaii for Pacific Ocean patients for example.

### The future of islands and LVADs

Establishing LVAD programs on most islands is not feasible, cost-effective, nor a sustainable strategy to HF in island regions. However, as larger islands become more experienced in LVAD placements and post-op patient care, a more centralized/regionalized patient care strategy should be developed in order to care for those patients who simply cannot attain a new heart. Additionally, with the current withdrawal of the Heartware (Medtronic, Minneapolis, Minn) from the market, different approaches are being implemented to ensure patient safety for the future LVAD systems. Newer technologies such as the Impella 5.5 (Abiomed, Danvers, Massachusetts, USA) assist device are gaining ground in the USA as a transitioning and bridging approach [19]. Although to date FDA approves a limited 2-week implant duration using this technology, its use has shown success in patients for up to 2 months; this option opens doors to the possibility of less invasive horizons to heart failure patients even in remote regions especially for island states [19]. Finally, although any LVAD training requires specific implantation and perioperative training at experienced mainland centers, some islands have their own cardiac surgery training programs. There are currently four islands with cardiothoracic surgery training programs, Cuba, Jamaica, Martinique, and Singapore. The advantage these programs have with regard to future

practice, is that residents grow into an already island-based environment and therefore are more comfortable working in these settings [6].

### Solutions to the challenges following implantation

Despite the many benefits of LVADs, postoperative treatment, follow-up and specialized medical care remain a challenge. One thing is successfully implanting an LVAD; the other is being prepared for the possible and eventual complications associated with these devices [20]. In the ROADMAP study, at 2 years following implantation, only 8% had freedom from re-hospitalization; the main cause was bleeding. Other complications such as thrombosis, stroke, infections, and worsening heart failure are all possible adverse events that the LVAD team should be ready to face [20]. Not only do these complications imply re-hospitalizations, but require a sophisticated team of nurses, device technicians, and heart failure specialists all working in synchrony to stabilize these events. In response to these very real complications of LVADs, island regions must have a nearby centralized center capable of managing complications and adverse events. For a technology that is designed and aimed towards these highly complex patients, especially in island regions, a hub-and-spoke type organization is critical to properly treat and resolve these highly likely events [21]. In these models, larger islands may function as hubs while more disperse and smaller centers may fill a spoke-type profile and category. This of course can function within a well-established and organized healthcare system [21].

### Conclusions

The pursuit of improving cardiac surgical care in underserved regions of the world drives innovation and newer strategies. For HF patients living in island regions, special attention should be paid as many of these patients do not have the luxury of specialized mainland surgical care. The continuous quest for a solution to HF in island regions should include the establishing of high-quality LVAD programs in a transfer-network system and hub-and-spoke model designed for those patients not candidates for long-distance air-bridging.

### Abbreviations

LVAD: Left ventricular assist device; HF: Heart failure; LMIC: Low-middle-income countries.

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None.

### Authors' contributions

Eric Vinck: writing, drafting, research, organization. Dominique Vervoort: writing, draft, final review. Kaushal Tiwari: writing, conceptualization, supervision. Ahmet Kilic: writing, supervision, conceptualization. Benjamin Smood: writing,

final drafting, research. Juan Rendon: supervision, writing, drafting, research. Jose Escobar: supervision, writing, drafting, research. Alejandro Quintero: supervision, writing, drafting, research. Meindert Palmen: conceptualization, supervision, final draft. Robert Klautz: conceptualization, supervision, final draft. The authors read and approved the final manuscript.

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