JACC: HEART FAILURE VOL. 3, NO. 4, 2015

ISSN 2213-1779/$36.00
PUBLISHED BY ELSEVIER INC. http://dx.doi.org/10.1016/j.jchf.2014.10.011

MINI-FOCUS ISSUE: MECHANICAL SUPPORT AND BLEEDING

CLINICAL RESEARCH

Left Atrial Decompression Pump for Severe Heart Failure With Preserved Ejection Fraction

Theoretical and Clinical Considerations

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ABSTRACT

OBJECTIVES The purpose of this study was to provide insight into the potential for left atrium (LA) to aortic mechanical circulatory support as a treatment for patients with heart failure with preserved ejection fraction (HFpEF).

BACKGROUND Although HFpEF arises from different etiologies, 1 hallmark of all forms of this syndrome is a small or minimally-dilated left ventricle (LV). Consequently, the use of traditional mechanical circulatory support in end-stage patients has been difficult. In contrast, HFpEF is also characterized by a large LA.

METHODS Hemodynamic characteristics of 4 distinct HFpEF phenotypes were characterized from the published data: 1) hypertrophic cardiomyopathies; 2) infiltrative diseases; 3) nonhypertrophic HFpEF; and 4) HFpEF with common cardiovascular comorbidities (e.g., hypertension). Employing a previously-described cardiovascular simulation, the effects of a low-flow, micropump-based LA decompression device were modeled. The effect of sourcing blood from the LV versus the LA was compared.

RESULTS For all HFpEF phenotypes, mechanical circulatory support significantly increased cardiac output, provided a mild increase in blood pressure, and markedly reduced pulmonary and LA pressures. LV sourcing of blood reduced LV end-systolic volume into a range likely to induce suction. With LA sourcing, however, LV end-systolic volume increased compared with baseline. Due to pre-existing LA enlargement, LA volumes remained sufficiently elevated, thus minimizing the risk of suction.

CONCLUSIONS This theoretical analysis suggests that a strategy involving pumping blood from the LA to the arterial system may provide a viable option for end-stage HFpEF. Special considerations apply to each of the 4 types of HFpEF phenotypes described. Finally, an HFpEF-specific clinical profile scoring system (such as that of INTERMACS [Interagency Registry for Mechanically Assisted Circulatory Support]) would aid in the selection of patients with the appropriate risk-benefit ratio for implantation of an active pump. (J Am Coll Cardiol HF 2015;3:275–82)

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Manuscript received July 7, 2014; revised manuscript received September 26, 2014, accepted October 3, 2014.

ABBREVIATIONS AND ACRONYMS

CO = cardiac output

HCM = hypertrophic cardiomyopathy

HFpEF = heart failure with preserved ejection fraction

HFrEF = heart failure with reduced ejection fraction

HTN = hypertension

LA = left atrium/atrial

LV = left ventricle/ventricular

MCS = mechanical circulatory support

NYHA = New York Heart Association

PCWP = pulmonary capillary wedge pressure

RCM = restrictive cardiomyopathy

VAD = ventricular assist device

Heart failure with preserved ejection fraction (HFpEF) is an umbrella term that covers a relatively wide range of diseases with different underlying etiologies, pathophysiologies, and constellations of comorbid conditions (1–3). Although there is no agreed-upon classification system for subdividing HFpEF patients, 1 system proposes 4 broad categories (**Table 1**). In addition to different chamber properties, these categories also segregate patients with different hemodynamic profiles. Regardless of etiology, patients with HFpEF have equally poor prognosis and quality of life as patients with heart failure and reduced ejection fraction (HFrEF). Although the prevalence and incidence of HFpEF is increasing (3), no study has yet proven a benefit from any specific treatment. Accordingly, patients with HFpEF have no evidence-based treatment options for persistent severe symptoms.

Left ventricular assist devices (VADs) have now been tested widely in end-stage HFrEF patients for bridge to transplant, bridge to decision, destination therapy, and bridge to recovery (4–6). However, there has been only limited experience with VADs in HFpEF (7–12). Some authors have even listed certain forms of HFpEF (e.g., hypertrophic cardiomyopathy [HCM]) as a contraindication for VAD therapy (13). The specific concern stems from the smaller left ventricular (LV) chamber sizes characteristic of HFpEF that can lead to obstruction of flow into the LV inflow cannula (7).

More recently, a micropump-based form of circulatory support has been introduced in which pump inflow is derived from the left atrium (LA), actively decompressing the LA and pulmonary circulation while improving systemic blood flow (The Synergy System, HeartWare International, Framingham, Massachusetts) (14). These features are particularly relevant for the HFpEF population, because a common feature of all forms of HFpEF is an enlarged LA. Other novel features of this micropump are that it is designed to be implanted in a subcutaneous pacemaker-like pocket (outside of the thorax), outflow is delivered to the subclavian artery, and the implant is via a minimally-invasive procedure. The pump is designed to provide partial mechanical support (2 to 4 l/min) and reduce LA pressure, and for HFrEF patients, the system is intended for use in INTERMACS (Interagency Registry for Mechanically Assisted Circulatory Support) profiles 4, 5, and 6 (15).

The purpose of this study is to elucidate the theoretical hemodynamic effects of the Synergy System in patients with different forms of HFpEF using a previously-described cardiovascular simulation (16,17) that successfully predicted hemodynamic effects of Synergy use in HFrEF (14). Clinical considerations regarding *when* device implantation might be considered appropriate for an HFpEF patient are also discussed.

METHODS

HFpEF PHENOTYPES AND BASELINE HEMODYNAMICS. Four categories of HFpEF are listed in **Table 1**. Corresponding representative hemodynamic profiles are shown in **Table 2**. Type 1 HFpEF includes patients with HCM on the basis of inherited genetic mutation. Representative hemodynamics for this group were obtained from the subset of HCM patients reported by Kato et al. (18) who underwent heart transplant for intractable symptoms and had an LV ejection fraction (EF) ≥50%. Type 2 HFpEF includes patients with restrictive forms of cardiomyopathy, such as infiltrative diseases and endomyocardial fibrosis. One of the more common forms of type 2 HFpEF is amyloid cardiomyopathy. Representative hemodynamics for

TABLE 1 Categories of HFpEF

Type	Category	Key Features	Mechanism(s)	Cause of Heart Failure Syndrome
Type 1	Hypertrophic cardiomyopathy	Thick LV walls, small LV chamber	Genetic mutations	Diastolic dysfunction
Type 2	Infiltrative cardiomyopathies	Small chamber, generally have ↑ wall thickness, common to have RV involvement	Amyloid, sarcoid, hemochromatosis, endomyocardial fibrotic disease, etc.	Diastolic dysfunction, restrictive physiology
Type 3	Nonhypertrophic cardiomyopathy, without significant CV disease (non-LVH)	Normal wall thickness, small or normal chamber size, no significant physiologic stimuli for hypertrophy	Unknown (possible genetic abnormality)	Diastolic dysfunction (with or without restrictive physiology)
Type 4	1 or more underlying cardiovascular conditions	Varying combinations of HTN, MI, CAD, DM, CKD, obesity, etc.	Chronic neurohormonal activation, renal dysfunction, abnormal salt/water metabolism	Hypothesized to be due to volume overload state

CAD = coronary artery disease; CKD = chronic kidney disease; CV = cardiovascular; DM = diabetes mellitus; HFpEF = heart failure with preserved ejection fraction; HTN = hypertension; LV = left ventricular/ventricle; LVH = left ventricular hypertrophy; MI = myocardial infarction; RV = right ventricular.