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CASE REPORT

A rise in left atrial pressure detected by the V-LAP™ system for patients with heart failure during the coronavirus disease 2019 pandemic

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Abstract

During the coronavirus disease 2019 (COVID-19) pandemic, many patients refrained from inpatient medical care. For those inflicted with heart failure (HF), the risk of repeat hospitalizations is particularly high in case of infection. This presents an important opportunity for remote monitoring of haemodynamic data for these patients, in order to detect and treat accordingly. The aim of the present case is to report of the first measurements of a novel wireless left atrial pressure (LAP) monitoring system, the V-LAP™ (Vectorious Medical Technologies, Ltd), during the COVID-19 pandemic. The V-LAP™ Left Atrium Monitoring systEm for Patients With Chronic sysTOlic & Diastolic Congestive heart Failure (VECTOR-HF) is a first-in-man clinical study assessing the safety and feasibility of the V-LAP™ monitoring system. Our first patient, a 59-year-old man with severe ischaemic cardiomyopathy (left ventricular ejection fraction −30%) was enrolled prior to the COVID-19 outbreak. As per protocol, both the patient and the medical team were blinded to the results in the first 3 months after implantation. We were able to witness the LAP during the pandemic, as the patient remained undertreated, demonstrating a gradual increase from a mean pressure of 6.56 to 19.4 mmHg, as well as prominent V waves, before the data became available to the medical team and the patient was treated accordingly. Thereafter, pressures have returned to low values. This case demonstrated the feasibility of remote monitoring of LAP using the V-LAP™ system, as well as the potential benefit of remote care of HF patients.

Keywords Heart failure; Telemonitoring; COVID-19

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Introduction

The coronavirus disease 2019 (COVID-19) pandemic presents many unique challenges when caring for patients with cardiovascular disease. While these patients face a greater risk of developing severe form of COVID-19,[1–4] several reports have demonstrated the secondary adverse effects of social distancing and avoidance of potentially proper medical care for several cardiovascular conditions, putting these patients at risk for complications and death.[5–9]

For patients with symptomatic heart failure (HF), maintaining optimal medical surveillance and therapy is important to avoid acute decompensations and complications. For most HF patients, volume status is assessed by clinical evaluation of body weight or jugular venous pressure. However, changes in these parameters appear late within the natural history of HF decompensation and are relatively unreliable. For example, daily measurement of body weight has a very low sensitivity for the development of a new HF exacerbation.[10,11] On the contrary, previous remote monitoring techniques have shown efficacy in reducing the risk for hospital admissions, especially when invasive haemodynamic data are acquired.[12,13] In particular, the recent emergence of the Food and Drug Administration-approved CardioMEMS remote wireless pulmonary artery pressure (PAP) monitoring system represents a major breakthrough in the paradigm of acute decompensated HF event prevention, showing for the first time efficacy in reducing hospitalizations by remote monitoring of pressures in the cardiovascular system.[12] However, the CardioMEMS technology is based on measurement of PAP,

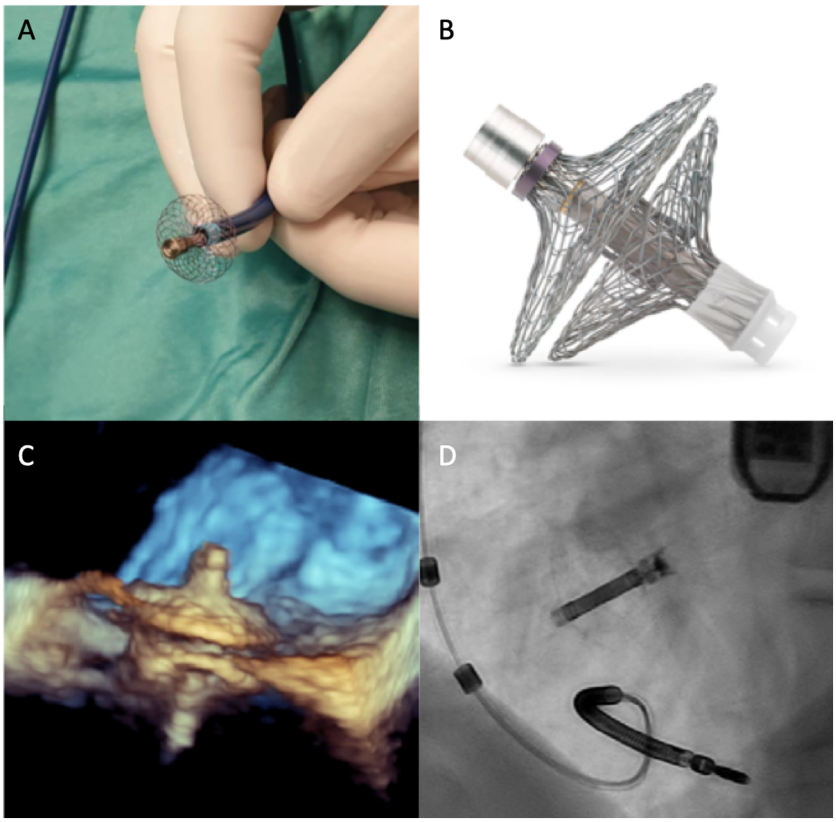
and until now, a direct 'left-sided' monitoring system has not been available for HF patients. This may be significant, because approximately 90% of patients admitted to the hospital for HF have pulmonary congestion related to elevated left atrial pressure (LAP).[14] PAP sensors are also less indicative of congestion in cases of post-capillary pulmonary hypertension, as is common in cases of HF with preserved ejection fraction. Therefore, PAP may be unreliable in estimating left-sided filling pressures in cases of increased pulmonary resistance, which occurs in more than 50% of patients with advanced HF.[15] Finally, direct intra-cardiac information of pressure allows for increased sensitivity for other pathological entities to be detected, such as mitral regurgitation,[16] myocardial ischaemia,[17] and atrial arrhythmias. Therefore, LAP measurement may contribute significantly to the prognostic information of patient with HF, detect the first stage of HF exacerbations, and discover acute events that hold significant clinical value.

The V-LAP™ (Vectorious Medical Technologies, Ltd) system measures LAP and enables bi-directional communications with an external unit, designed to monitor HF patients remotely. The implant is wireless, transmitting daily haemodynamic data to a secure cloud-based platform. The system includes a leadless implant, positioned across the inter-atrial septum (*Figure 1*), as well as an external unit and a dedicated delivery system. The implant is deployed in a trans-septal access, under angiographic and echocardiographic guidance (*Figure 1*). The external unit powers the implant and collects data via radio frequency communication upon activation, designed to be operated on a daily basis.[18]

The V-LAP™ Left Atrium Monitoring systEm for Patients With Chronic sysTOlic & Diastolic Congestive heart Failure (VECTOR-HF) first-in-man clinical study is a prospective, multi-centre, single arm, open-label clinical trial to assess the safety, performance, and usability of the V-LAP system in patients with New York Heart Association (NYHA) Class III HF (NCT03775161). According to the study design, patients and their caregivers are not exposed to the LAP measurements in the first 3 months after the V-LAP implant deployment. Major endpoints include the successful deployment of the implant, as well as safety outcomes. Secondary endpoints include accurate pressure measurements, as correlated with pulmonary capillary wedge pressure (PCWP), as well as number of HF admissions, changes in NYHA class, 6 min walk test, patient global assessment, Kansas City Cardiomyopathy Questionnaire, and pro-BNP at 6 months.

In Israel, a rapid response to the pandemic on a national level included the closing of the international borders quickly

Figure 1 The V-LAP™ implant (A), prior to implantation (B), three-dimensional trans-oesophageal image immediately following implantation (C), and fluoroscopy demonstrating the opaque device tube, and the anchoring system is non-opaque (D).



after the outbreak in China, quarantine of travellers returning from high-risk areas, and finally an official lockdown issued by the Ministry of Health on 25 March.[19] Rates of mortality have been relatively low, so far, but a similar trend of lower rates of admissions may be apparent.[20]

We are now able to report of the first patient implanted with the V-LAP™ at our institution, as part of the VECTOR-HF study. Owing to the strict prohibitions and tendency for avoidance of medical care during the COVID-19 pandemic, we examined the effects of the pandemic period on left-sided haemodynamics in our implanted patient.

Case report

The first patient enrolled to the VECTOR-HF at our institution is a 59-year-old man with severe ischaemic cardiomyopathy (left ventricular ejection fraction −30%) and past medical history of diabetes, chronic obstructive pulmonary disease, and hypertension. Despite receiving optimal medical therapy, which included bisoprolol, spironolactone, hydralazine, digoxin, and sacubitril/valsartan, the patient was symptomatic, with an NYHA functional class III, and had been admitted repeatedly for acute decompensation of HF. He was implanted with the V-LAP™ on 12 February, under fluoroscopy and trans-oesophageal echocardiography guidance, in a trans-septal fashion (*Figure 1* Immediately following implantation, the battery-free inter-atrial device captured LAP and reported it to a secure cloud-based database (*Figure 2*). As part of the first-in human protocol, the data were initially not exposed to the HF teams and became apparent only 3 months after deployment. Quite simultaneously, the COVID-19 restrictions began to take place, and the patient had not visited the HF clinic. During this time, the mean LAP had risen from a mean of 6.56 mmHg at the beginning of March to 19.4 mmHg at the end of May, also exhibiting significant V waves (*Figure 3*). Per protocol, we could not instruct the patient to change his medications until 3 months have elapsed following V-LAP™ implantation. *Figure 3* shows a weekly mean measurement of the LAP, demonstrating a slow rise in intra-cardiac pressures. The device also demonstrated a higher heart rate during the ambulatory

Figure 2 V-LAP™ measurement of left atrial pressure on 1 March (A) and 24 May (B), demonstrating differences in mean pressure.

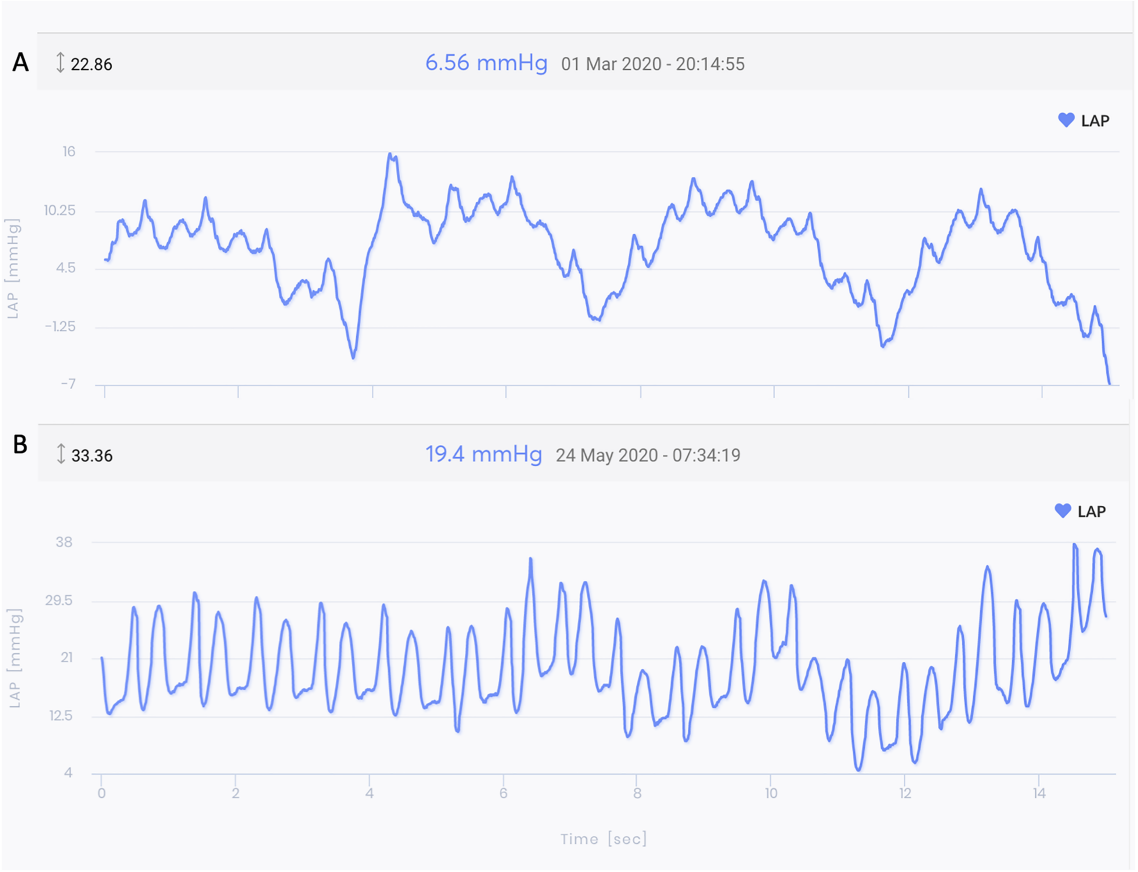


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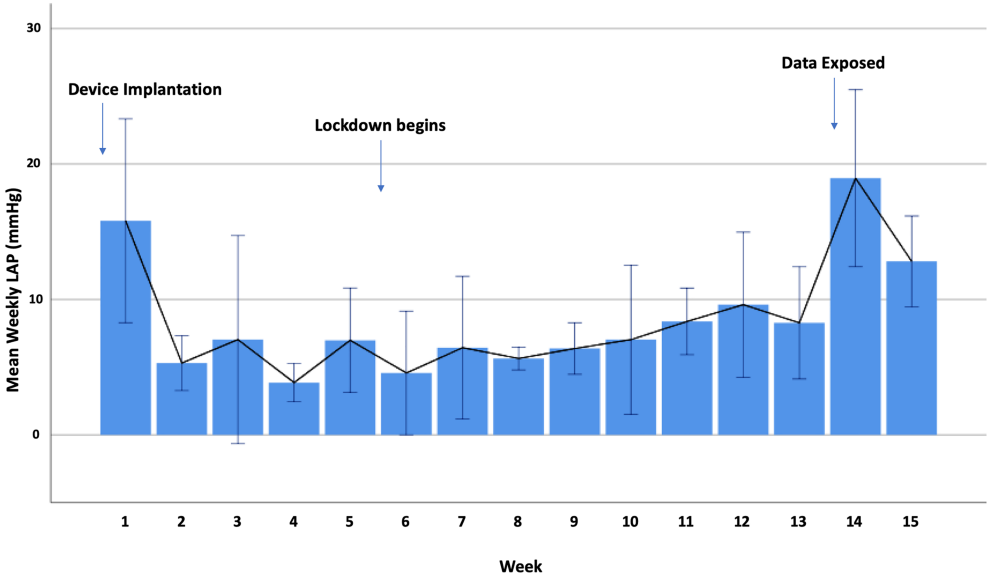
Figure 3 Mean weekly value of left atrial pressure during the coronavirus disease 2019 (COVID-19) pandemic.



measurements, in the range of 70–90 b.p.m. Upon his first visit to the hospital on 24 May, information was reviewed by the HF team for the first time, and a medical dose adjustment was performed: the dosage of beta-blockers was doubled, diuretics were increased for a week (*Table 1*), and the patient was reminded to reduce the amount of sodium in his diet. Immediately thereafter, a comparison of the device with mean PCWP by invasive haemodynamic study showed complete calibration between measurements: 9 mmHg mean wedge pressure and a V wave of 10–11 mmHg by haemodynamic study, and 9 mmHg measured by the V-LAP™ (*Table 2*). The patient now undergoes remote monitoring of LAP and medical dose adjustment by the HF team at our medical institution, demonstrating low LAP, and is currently completely asymptomatic.

Table 1 Medications received before and after measurement by the V-LAP

Medication	At 3 months	After dose adjustment
Aspirin (mg)	100 q.d.	100 q.d.
Clopidogrel (mg)	75 q.d.	75 q.d.
Atorvastatin (mg)	20 q.d.	20 q.d.
Spironolactone (mg)	50 q.d.	50 q.d.
Insulin glargine (units)	12 q.d.	12 q.d.
Insulin glulisine (units)	8 b.i.d.	8 b.i.d.
Empagliflozin (mg)	10 q.d.	10 q.d.
Sacubitril/valsartan (mg)	200 b.i.d.	200 b.i.d.
Hydralazine (mg)	12.5 t.i.d.	12.5 t.i.d.
Bisoprolol (mg)	2.5 b.i.d.	5 b.i.d.
Fusid (mg)	20 q.d.	40 b.i.d.

Discussion

In this report, we have seen a gradual rise in LAP during the COVID-19 pandemic, until medical care according to LAP measurements became available. In this specific example, we have seen what may be occurring for many patients with HF, and indeed other chronic conditions: social distancing and avoidance of face-to-face interaction with medical teams had most likely contributed significantly to non-optimal medical care and potentially serious adverse events. This represents an important opportunity for the emergence of remote medical monitoring.

Hospitalization rates for HF remain unacceptably high and are associated with substantial burden. Until recently, clinical trials of non-invasive remote medical systems have mostly failed to demonstrate improved outcomes, when compared with those of controls.[21,22] This is probably due to the quality of data derived from such solutions. In contrast, remote PAP-guided management has demonstrated to reduce HF hospitalization and all-cause mortality in selected symptomatic HF patients in the CHAMPION trial. Direct information of left-sided filling pressures holds potential advantages over PAP and seemed promising with one pacemaker-like device,[23] but the pivotal trial was halted early owing to the cumbersome design of the device and device-related complications.[24] The V-LAP™ monitoring system is designed to gather LAP data in a remote manner, harnessing upon advanced technologies that enable a fully digital, miniature design. These theoretically should enable the system to enable direct intra-cardiac information to be gathered in a safe and

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Table 2 Hemodynamic and Echocardiographic data

	Haemodynamic pressure measurements (mmHg)					
	LAP	Mean PCWP	PCWP V wave	Mean RAP	Systolic RV	sPAP
First measurement	6.56	7.0	8.0	5.0	24.0	25.0
At 3 months	19.4	18.0	19.0	9.0	31.0	32.0
After dose adjustment	9.0	9.0	11.0	6.0	25.0	27.0

	Trans-thoracic echocardiography					
	LVEF (%)	LVEDD (mm)	LVESD (mm)	sPAP (mmHg)	LA volume (ml)	TAPSE (mm)
Before implantation	30	57.0	43.0	32.0	71.0	24.0
At 3 months	30	59.0	44.0	42.0	74.0	22.0

Abbreviations: LAP, left atrial pressure; PCWP, pulmonary capillary wedge pressure; RAP, right atrial pressure; RV, right ventricular; sPAP, systolic pulmonary artery pressure; LVEF, left ventricular ejection fraction; LVEDD, left ventricular end diastolic diameter; LVESD, left ventricular end systolic diameter; LA, left atrial; TAPSE, tricuspid annular plane systolic excursion.

robust manner, possibly posing unique clinical advantages over present solutions, in the accurate detection of left-sided filling pressures in patients with HF, as well as diagnosis of important adverse events.

As we await the full results of the first-in human experience with the V-LAP™ monitoring system, this case implies that remote patient management guided by invasive means has the potential to significantly improve patient management and/or outcomes, without the need for physical presence at the hospital. The COVID-19 pandemic has highlighted the importance of safe and clinically appropriate solutions for remote telemonitoring in patients with HF, and the future of this field seems promising.

Conflict of interest

L. Perl owns shares and has received consulting fees from Vectorious Medical Technologies. The other authors have no conflict of interest to declare.

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