Novel devices

Telemonitoring in chronic heart failure

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Clinical management of refractory heart failure remains challenging, with a high rate of rehospitalizations despite advances in medical and device therapy. Care can be provided in person, via telehomecare (by telephone), or telemonitoring, which involves wireless technology for remote follow-up. Telemonitoring wirelessly transmits parameters such as weight, heart rate, or blood pressure for review by health-care professionals. Cardiac implantable devices (defibrillators and cardiac resynchronization therapy) also transmit continually interrogated physiological data, such as heart rate variability or intrathoracic impedance, which may be of value to predict patients at greater risk of hospitalization for heart failure. The use of remote monitoring techniques facilitates a rapid and regular review of such data by health-care workers as part of a heart failure management programme. Current evidence supports the feasibility of such an approach but routinely assessed parameters have been shown not to impact patient outcomes. Devices that directly assess cardiac haemodynamic status through invasive measurement of pressures are currently under investigation and could potentially increase the sensitivity and specificity of predicting heart failure events. The current evidence for telemonitoring and remote monitoring, including implantable haemodynamic devices, will be reviewed.

Keywords

Intrathoracic impedance • Telehomecare • Telemonitoring • Haemodynamic monitoring • Intracardiac pressures

Introduction

Despite advances in pharmacological and device therapy for chronic heart failure management, progression of heart failure remains a health-care burden. Clinical management to prevent acute decompensation and/or admission in the ambulatory heart failure population remains challenging. Heart failure disease management programmes have emerged to aid in educating patients, provide evidence-based care, and improve outcomes. Frequent monitoring of patients is a cornerstone of care, which occurs in person with clinic visits, using structured or semi-structured assessments over the telephone (telehomecare), or via telemonitoring. Telemonitoring involves the transfer of physiological data from patients at home to their health-care provider. Potentially, this allows more frequent assessment of a patient’s heart failure status and earlier recognition of haemodynamic deterioration than would be feasible in standard clinical practice. This concept has been studied using patient-activated automatic devices to provide measurements of parameters such as weight, heart rate, rhythm, and blood pressure.

Results of studies have been contradictory, with many of the studies being small or having variable endpoints. However, meta-analyses have suggested that telemonitoring and telephone support may provide better clinical outcomes than usual care, with a reduction in mortality and hospital admissions observed.1,2 In the Cochrane Review3 undertaken by Inglis et al., 25 full peer-reviewed studies were included in the analysis and incorporated 8323 patients. In addition to examining the impact on heart failure-related hospitalization and mortality, the review also considered the quality of life (QOL), acceptability of the systems, and cost efficacy. Telemonitoring reduced all-cause mortality [relative risk (RR) 0.66, 95% confidence interval (CI) 0.54–0.81, \( P = 0.0001 \)], whereas telephone support demonstrated a non-significant reduction (RR 0.88, 95% CI 0.76–1.01, \( P = 0.08 \)). Both telemonitoring and telephone support produced significant reductions in heart failure-related hospitalizations (RR 0.79, 95% CI 0.67–0.94, \( P = 0.008 \) and RR 0.77, 95% CI 0.68–0.87, \( P < 0.0001 \), respectively). Acceptability of the technology was uniformly high and, despite concerns that the elderly would not be capable of managing the technology, there were
no demographic groups who appeared less likely to benefit. Twelve studies examined in the review reported cost efficacy, with nine reporting cost savings between 35 and 86%. Set-up cost was related to the level of technology employed.

Recently, these findings have been challenged by two large multicentred randomized trials. In the TIM-HF study, recently presented, 710 patients with class II or III heart failure, ejection fraction (EF) ≤ 35%, and on optimal medical therapy were randomized to usual care (356) or daily telemonitoring (354) and followed up over 2 years. There was no difference in hospitalization or survival between the two limbs, although potential benefit was suggested in subgroup analysis for those with prior heart failure hospitalization and EF >25%. In the study from Chaudhry, patients with a history of heart failure admission within 30 days were randomized to either telemonitoring or usual care. Baseline characteristics were similar between groups and adherence to the 6-month follow-up was no different at 79%. Those studied were relatively young with a median age of 61 years. Usual care was defined as adherence to AHA guidelines but no other details, such as frequency of outpatient review, were provided. There was no difference in the primary endpoint of hospitalization or death within 180 days. Telemonitoring failed to reduce the secondary endpoints of heart failure hospitalization, duration of hospitalization, or frequency of hospitalization. Subgroup analysis did not suggest any demographics likely to predict benefit. Compliance was a significant issue with 14% of those randomized to telemonitoring never using the system and only 55% using the system more than three times a week by the end of the study.

Remote monitoring of implantable cardiac defibrillators (ICD) and cardiac resynchronization therapy (CRT) devices is rapidly becoming the standard of care and is endorsed in a recent expert consensus. Follow-up of devices evaluating basic functions and parameters is now a routine clinical practice, has been shown to be safe and cost-effective, and is reimbursed within the USA. When these devices are used in heart failure patients, it would seem logical to utilize the remote monitoring capabilities and infrastructure already incorporated with the additional physiological information provided by devices into the overall evaluation of the patient. Although differences exist between manufacturers in technology used and parameters assessed, the concepts are similar (Table 1). The device wirelessly transmits monitored data from its memory to an external transmitter which relays the encrypted information on to the manufacturer’s central database. The information is then made available to the physician on the Internet. Information is transmitted at regularly prescribed and adjustable intervals; whenever pre-agreed alert situations arise, such as the onset of atrial fibrillation (AF) or evidence of lead damage, alerts are forwarded to the physician by email, fax, or short message service.

Table 1  Comparison of heart failure monitoring capabilities of devices

<table>
<thead>
<tr>
<th></th>
<th>Biotronik Home Monitoring™</th>
<th>Boston Scientific Latitude™</th>
<th>Medtronic CareLink™</th>
<th>St Jude Merlin.net™</th>
</tr>
</thead>
<tbody>
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<td>Analogue phoneline</td>
<td>Analogue phoneline</td>
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<td>Yes</td>
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<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Activity levels</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
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</tr>
<tr>
<td>Heat rate variability</td>
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<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Thoracic impedance</td>
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</tr>
</tbody>
</table>

GSM, global system for mobile communications.

Currently evaluated parameters

Certain basic parameters routinely monitored by devices (such as percentage of ventricular pacing, presence of arrhythmia, activity levels, and mean heart rates at rest or during exertion) may provide an indication of the patient’s clinical status (Figure 1) or impending cardiac decompensation. Time to physician awareness of these changes is reduced by implantable devices with wireless data transmission capability compared with conventional care. In a pilot study of the Home Care trial, these simple criteria were observed to change in the week preceding hospitalization for heart failure. Whether this early detection has an impact on patient management or outcome has only been evaluated in small studies but is the focus of ongoing studies.

Heart rate variability (HRV), a measure of autonomic nervous system tone, can be estimated by most CRT devices. Adamson et al. examined the value of HRV as calculated by an implanted CRT device, defined as the standard deviation of 5 min median atrial-to-atrial intervals (SDAAM). Of the 288 patients studied, 34 were hospitalized and, in these patients, the SDAAM declined from a baseline 76 ± 27 to 64 ± 26 ms. It was noted that the SDAAM was persistently lower in those patients who were hospitalized or died. Retrospectively, applying an algorithm derived using data from the first 14 hospitalized patients to the remaining 20 patients suggested a sensitivity for detecting hospitalization of 70%. However, using this algorithm would be associated with an estimated false-positive detection of 3.4 times per year. Despite this concern, the SDAAM was still more sensitive and specific than measures of activity or nocturnal heart rate.

The combination of device-derived data plus patient weight and symptoms, as recorded by the Latitude system, is an extension of conventional practice but did not improve predication of heart
failure decompensation events (HFE) in the Decompensation Detection Study (DECODE). In this study, patients with an episode of cardiac decompensation were matched to another patient from the same centre and followed prospectively. A probability model to detect HFE was constructed using weight, symptoms, lead impedance, and HRV. A 48% sensitivity for early detection of HFE was demonstrated with two false-positive events per patient per year. The Remote Active Monitoring in Patients with Heart Failure (Rapid-RF) study is evaluating the same parameters in a prospective registry enrolling 1000 patients in 100 sites. Preliminary reports suggest a good compliance with the regimen and that the majority of alerts are related to weight rather than device-based information. The predictive value has not been estimated.

The intrathoracic impedance can be evaluated by applying a sub-threshold electrical impulse between a pacemaker lead tip and the device. The cyclic changes that occur with respiration have long been used to assess respiratory rate and minute ventilation (MV), hence guiding rate response. More recently, alterations in the levels of MV at rest and during exercise have been combined with estimates of activity levels, detected by accelerometers within the pacemakers, to detect cardiac decompensation. Page et al. examined a 7-day average of MV recorded at rest and during exertion in 48 patients with heart failure (total follow-up 195 months). An expert system was constructed and, when applied retrospectively to the data, correctly predicted 22 of 25 heart failure events, also suggesting a further 9 false-positive events.

Gradual and progressive changes in thoracic impedance may also be caused by pulmonary congestion. In the Medtronic Impedance Diagnostics in Heart Failure Patients Trial (Mid HeFt), the intrathoracic impedance, measured by modified pacemakers, was shown to have inverse correlation with the left ventricular (LV) filling pressure in patients receiving treatment for heart failure. Observed changes preceded patient symptoms and hospitalization. The findings of this study were used to derive the Optivol algorithm currently employed in Medtronic devices. With this algorithm, the intrathoracic impedance is measured every 20 min from midnight to 5 a.m. The difference between the daily mean impedance and a rolling reference value is used to derive a fluid index. When the fluid index exceeds a pre-programmed threshold, an audible or remote monitoring alert is triggered. This system is in widespread clinical use and, in a retrospective clinical study of 156 patients, was shown to be superior to weight gain in predicting decompensation. This difference may have partly been related to compliance issues regarding weight measurements, but the impedance assessment had an estimated sensitivity of predicting heart failure events of 76.4% vs. 22.5% with weight. The false-positive rate was also lower when impedance measurement was compared with weight assessment, 1.9 vs. 4.3 events per patient per year. The importance of threshold level on sensitivity and specificity was highlighted by Ypenburg et al. A study of 115 patients showed that the default threshold value of 60 V had a specificity of only 33%. Receiver operator curve analysis suggested that a sensitivity of 60% and a specificity of 73% would have been achieved with a threshold of 120 V.

An alternative approach was used in the PARTNERS study where the fluid index was combined in an algorithm with measures of activity, arrhythmias, and heart rate. A diagnostic heart failure result was defined as a fluid index of >100 Ω or any two of prolonged AF episode, rapid ventricular rate during AF, high fluid index (≥60 Ω), low patient activity, low HRV, high night heart rates, low percentage of CRT pacing, or ICD shocks. Compared with patients who had negative diagnostic information, patients with a positive combined heart failure diagnostic had a significantly increased risk of heart failure hospitalization (hazard ratio 5.5, P < 0.0001).

Although currently employed diagnostics provide valuable adjuvant data in patient evaluation and enable physicians to identify those patients at greater risk of heart failure decompensation,
Right ventricular pressure sensor

The implantable haemodynamic monitoring (IHM) system measuring RV pressures incorporated a programmable device (Chronicle, model 9520, Medtronic, Minneapolis, MN, USA) similar to the pulse generator of a pacemaker and a modified unipolar pacemaker lead (model 4328A, Medtronic) with the pressure sensor located near the tip. Implantation is similar to that of a pacemaker or defibrillator with passive fixation of the lead into the RV outflow tract or septum (Figure 2). The patient carries a small external device, which aids in correcting for barometric pressure. The IHM system continuously monitors heart rate, body temperature, and haemodynamics; haemodynamic parameters include RV dP/dt (maximum rate of change in RV pressures), RV systolic and diastolic pressures, and ePAD, defined as the RV pressure at the time of pulmonary valve opening or maximal RV dP/dt.23,24 The RV-derived ePAD has been shown to correlate with PA diastolic pressures (r = 0.87 at baseline and 1 year) and thus, as an approximation of left-sided filling pressures.21

Early experience with this IHM device suggested a benefit with volume management and a positive impact on heart failure hospitalizations,22 leading to the COMPASS-HF study (Chronicle Offers Management to Patients with Advanced Signs and Symptoms of Heart Failure).25 COMPASS-HF was a multicentre, randomized, single-blind, parallel controlled trial enrolling 274 patients with NYHA class III–IV symptoms, regardless of EF. All patients received the device, but intracardiac pressures were used for patient management in the treatment group only. The two primary safety endpoints were met with no pressure-sensor failures and a 91.5% complication-free rate; the majority of system-related complications were lead issues, such as dislodgement requiring repositioning. The study, however, did not find a significant difference in the primary efficacy endpoint of reduction in heart failure events (defined as hospitalizations, emergency, or urgent care visits requiring intravenous therapy) with a 21% reduction in the Chronicle group compared with the control (P = 0.33). Similar results were found in the subgroup analysis of 70 diastolic heart failure patients with preserved EF.26

It is possible that COMPASS-HF was underpowered, with a lower than expected event rate in the control group of 0.85, at least partially explained by the robust telephone contact schedule of the control patients—which occurred almost weekly. Other criticism of the study was lack of a control group without an implanted device. Retrospective analysis revealed a significant 36% reduction in the first heart failure-related hospitalization, although this was not a pre-specified endpoint.

Despite the lack of benefit in the primary endpoint, more patients in the treatment group underwent medication adjustment without contributing to over-diuresis and adverse effects on the event rate. Although this particular technology is not currently approved by the Food and Drug Administration, COMPASS-HF introduced IHM and lessons on setting a range of the practitioner. Remote haemodynamic monitoring allows a physician to play a proactive role in daily care through adjustment of pharmacological therapy based on a rise in invasive pressure measurements—prior to the development of symptoms or decompensation, potentially preventing inpatient admission. Right heart catheterization pressure measurements (i.e. using Swan–Ganz catheterization) have been used during inpatient care in a resting, supine state, but this is not practical in an outpatient setting.19,20 Early implantable continuous haemodynamic monitoring studies recorded comparable right ventricular (RV) and estimated pulmonary artery diastolic (ePAD) pressures to right heart catheterization at baseline and 1-year follow-up,21 along with an increase in these pressures during volume overload events a few days prior to hospitalization.22 Furthermore, invasive haemodynamic parameters returned to baseline after successful treatment of the clinical event. Subsequent trials have evaluated a variety of parameters to assess filling pressures in an ambulatory setting; these investigational devices include RV, pulmonary artery (PA), and left atrial pressure (LAP) sensors.

Investigational technologies and clinical trials for implantable haemodynamic monitoring

As previously mentioned, routine clinical management of heart failure focuses on the development of symptoms and following daily weights to assess volume retention, leading to a reactive role of the practitioner. Remote haemodynamic monitoring allows a physician to play a proactive role in daily care through adjustment of pharmacological therapy based on a rise in invasive pressure measurements—prior to the development of symptoms or decompensation, potentially preventing inpatient admission. Right heart catheterization pressure measurements (i.e. using Swan–Ganz catheterization) have been used during inpatient care in a resting, supine state, but this is not practical in an outpatient setting.19,20 Early implantable continuous haemodynamic monitoring studies recorded comparable right ventricular (RV) and estimated pulmonary artery diastolic (ePAD) pressures to right heart catheterization at baseline and 1-year follow-up,21 along with an increase in these pressures during volume overload events a few days prior to hospitalization.22 Furthermore, invasive

they have not yet been shown to impact patient outcomes and are not sufficiently accurate as to dictate therapy.

Figure 2 The implant procedure of the Chronicle implantable haemodynamic monitoring is similar to that of a cardiac pacemaker, whereby the device is positioned subcutaneously in the pectoral area with the lead positioned transvenously in the right ventricular outflow tract. Average implant time is \( \sim 1 \) h.
of target pressures, identifying staff to review the data, and incorporating an algorithm for timely adjustment in treatment during follow-up.

**Left atrial pressure sensor**

The HeartPOD device (St Jude Medical, Minneapolis, MN, USA) is a fully implantable apparatus that directly measures LAP, core temperature, and intracardiac electrogram. It is implanted percutaneously through transseptal puncture with the sensor lead placed inter-atrially; the lead extends into the vena cavae attaching to the coil antenna located subpectorally (Figure 3).

The Hemodynamically Guided Home Self-Therapy in Severe Heart Failure Patients (HOMEOSTASIS) trial was the first in-human study using the LAP sensor linked to a physician-directed patient self-management model. Forty patients with NYHA class III or IV heart failure, a minimum of one heart failure event requiring intravenous therapy within the previous year, and stable doses of optimal medical therapy were enrolled at a total of seven sites in the USA, Australia, and New Zealand. Anticoagulation included aspirin 150–325 mg/day and clopidogrel 75 mg/day for 6 months, unless already taking warfarin for other indications, in which case patients additionally received aspirin (150–325 mg/day). The sensor was powered by radiofrequency telemetry after placing an external handheld patient advisor module over the subcutaneous antenna. Readings were taken at scheduled morning and evening times and when symptoms deteriorated.

The study protocol included three designated time periods: (i) a blinded ‘observation period’ of the first 3 months during which treatment was based on clinical status, (ii) a ‘titration period’ consisting of the next 3 months during which treatment was guided by LAP readings in order to achieve an optimal LAP goal, and (iii) a ‘stability period’ consisting of the study duration in which therapy was individualized based on LAP readings and disclosed to patients. In the latter period, also referred to as ‘dynamic therapy’, five ranges of LAP were available (from very low to very high) for specific medication adjustment to reach the optimal LAP, therefore tailoring therapy to the individual patient. These changes primarily included titration of diuretics and vasodilators. Slightly more than half had a pre-existing cardiac resynchronization and/or defibrillator implant. Device implant was successful in all patients without early major adverse cardiac or neurological events, but two patients had late ischaemic events—stroke in a patient with pre-implant LV thrombus and the other with transient cranial nerve VII palsy without embolic source on echocardiography. A total of four patients had sensor lead malfunction (replacement in three) and 95% (n = 38) had functioning sensors guiding therapy at last follow-up.

Mean daily LAP was significantly reduced from 17.6 mmHg (95% CI 15.8–19.4 mmHg) in the observation period to 14.8 mmHg (95% CI 13.0–16.6 mmHg, P = 0.003) during pressure-guided therapy; the rate of LAP >25 mmHg was also significantly reduced by 67% (P = 0.001). These findings correlated with improvement in clinical parameters of NYHA class, QOL, EF (increase by 7 ± 10%, P < 0.001), pulmonary capillary wedge pressure, cardiac index, and stroke volume index. The event rate was also reduced after the initial observation period [hazard ratio 0.16 (0.04–0.68), P = 0.012]. Doses of angiotensin-converting enzyme inhibitors and β-blockers increased with a trend to reduction in loop diuretic dosing.

Major limitations include the small size, observational design, and lack of a true standard control group. However, the study demonstrates the temporal association of haemodynamic changes to clinical decompenation and the potential benefit of a physician-directed patient management strategy to improve clinical outcomes and further optimize anti-neurohormonal therapy. Advantages with this system involve direct measurement of left-sided filling pressures and the potential to promote patient compliance through ‘dynamic’ therapy, allowing patients more participation and/or control in their day-to-day management. Further investigation of the effectiveness of LAP-guided management on heart failure-related events is ongoing.

**Pulmonary artery pressure sensor**

Development of the heart failure sensor (HFS; CardioMEMS Inc., Atlanta, GA, USA) to measure PA pressures differs from the aforementioned sensors, in that it is a wireless device implanted through right heart catheterization (Figure 4). The HFS consists of a three-dimensional coil housed in a silicone, pressure-sensitive capacitor that is tethered into location by two nitinol loops to avoid migration. The device is 15 mm long and 3 mm wide and delivered through a catheter-based system from the femoral vein. Selective angiography confirms the appropriate diameter of 7–10 mm of the PA prior to HFS deployment. As previously mentioned, the HFS is not attached to a lead or internal antenna/generator; it is powered externally by an antenna placed on the back or side of the patient in the approximate location of the sensor. Detected frequency shifts are converted to a real-time pressure waveform, after calibrating for atmospheric pressure. Patients are continued on warfarin therapy if previously indicated for other reasons or placed on 30 days of aspirin/clopidogrel combination.
The design of the HFS with nitinol loops to secure position allows blood flow around the device as opposed to impairing flow in the PA; porcine studies did not show a pro-thrombotic effect on the PA.

The first human implant of the HFS was reported in 2007, and a subsequent study of 12 patients provided accurate measurements when compared with the Swan–Ganz catheterization and echocardiography at baseline and intermediate follow-up. The recent CHAMPION study (Primary Results of the CardioMEMS Heart Sensor Allows Monitoring of Pressure to Improve Outcomes in NYHA Class III Heart Failure Patients) is a multicentre, prospective, randomized controlled, single-blind clinical trial. The goal was to evaluate safety and efficacy of the HFS and the effectiveness of pressure-guided therapy in reducing heart failure-related hospitalizations in NYHA class III patients with episodes of acute decompensation. All patients (n = 550) received the device but physicians were blinded to readings in the control group. Pulmonary artery target pressures were systolic of 15–35 mmHg, diastolic of 8–20 mmHg, and mean of 10–25 mmHg utilizing neurohormonal, diuretic, and/or vasodilator therapy.

The study met safety endpoints of device/system-related complications with no sensor failures during follow-up. Management guided by the HFS resulted in a significant reduction in heart failure hospitalizations: 30% at 6 months (P < 0.001) and 38% in annualized rates (P < 0.0001). Improvement was also noted in mean PA pressures, QOL, days alive out of hospital, and the proportion of patients hospitalized. Implant time has decreased from 71 ± 31 min for early implants to ~7 min after the Swan–Ganz catheterization due to improvement in the delivery system and catheter/wire exchanges involved. Figure 5 details a case example from our institution of pressure-guided management in a patient implanted with an HFS. Comparing this IHM system with others, advantages are the straightforward implant through right heart catheterization, lack of battery changeout, and wireless feature of the sensor.

**Impedance monitoring and clinical trials**

Intrathoracic electrical impedance monitoring has been used as a tool to evaluate pulmonary congestion in cardiac resynchronization and defibrillator devices with suboptimal sensitivity. Concerns...
Impedance monitoring is limited by the inflammatory reaction that occurs around the lead early after implant, thereby affecting measurements for a duration of time. Further studies are needed to validate and define the implications, if any, of multiple vector intracardiac impedance monitoring in ambulatory heart failure patients and whether this information has potential to assess inter-intracardiac impedance monitoring in ambulatory heart failure measurements for a duration of time. Further studies are needed that occurs around the lead early after implant, thereby affecting objective haemodynamics obtained from LAP sensor.

A larger study found correlation between ICD impedance changes and reduction in LV volumes after CRT with the best correlation noted in LV tip-to-RV coil vector, which excludes non-cardiac tissue as opposed to the intrathoracic vector of RV coil-to-device.

Impedance vectors also appear to have variable responses to decompensated heart failure episodes. Khouy et al., measured impedance signals during multiple pacing configurations in animal models of heart failure implanted with a CRT device and correlated the obtained information with invasive haemodynamics. When compared with right-sided impedance signals, the authors found LV lead vectors to be more responsive to physiological changes during heart failure episodes and better correlated with objective haemodynamics obtained from LAP sensor.

Impedance monitoring is limited by the inflammatory reaction that occurs around the lead early after implant, thereby affecting measurements for a duration of time. Further studies are needed to validate and define the implications, if any, of multiple vector intracardiac impedance monitoring in ambulatory heart failure patients and whether this information has potential to assess inter-ventricular delays for the optimization of CRT programming.

Summary

Despite advances in the management of chronic heart failure, morbidity and mortality remain high with 20–30% patients readmitted after 30 days and almost 50% at 6 months. Effective adjustment of medical therapy relies on an accurate assessment of congestion and volume status, which is often limited based on current measures of physical findings and weight gain. Studies have indicated that haemodynamic decompensation often precedes clinical decompensation, leading to more intense monitoring of patients.

Clinical management involves in person care, telehomecare, and the emerging intervention of telemedicine or remote monitoring. Telemonitoring of basic physiological parameters has not lived up to initial promise and, in recent studies, had no positive impact.

Whether the remote monitoring of implanted devices which provide a greater range on physiological parameters, such as arrhythmia burden, thoracic impedance, and HRV, will impact on patient outcome has yet to be determined.

Implantable haemodynamic monitoring devices to directly assess invasive pressures are the focus of recent clinical trials, but still investigational and complications arising from these procedures could impair cost effectiveness. Impedance monitoring has primarily evaluated RV-dependent signals, but emerging studies will further evaluate the utility of multiple impedance vectors and if a role exists for combining impedance data with haemodynamic sensors. At this time, we do not know whether remote monitoring provides the best direction in managing ambulatory heart failure patients or whether it is simply a tool to identify suboptimal medical treatment. Evidence has been controversial, with some studies promising in terms of improving outcomes in this population but not yet extensively studied to dictate care. Remote monitoring, whether vital signs or data from implantable devices, serves as an adjunct to our current out-of-hospital management of advanced heart failure, assisting in further optimization of medical therapy, enhancing QOL and functional status, and improving outcomes.

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References

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