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A NOVEL, NON-INVASIVE AI-BASED TELEMONITORING SYSTEM FOR HEART FAILURE: DETECTION OF UNDIAGNOSED HYPERTHYROIDISM IN AN ASYMPTOMATIC PATIENT

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ABSTRACT

Background: Untreated thyroid disorders may precipitate heart failure (HF) decompensation. Assessment of cardiac filling pressures may aid in the early detection and prevention of clinical decompensation. Therapy guided by monitoring of cardiac filling pressures has been shown to improve quality of life and survival and reduce hospitalizations of individuals with HF. We have developed a non-invasive method to assess left ventricular filling pressures (LVFP) by analysing the photoplethysmography signal with Seeling HeartCore technology (Seerlinq, Bratislava, Slovakia).

Case description: A 99-year-old female visited the clinic for a routine cardiac check-up. Laboratory investigations showed elevated NTproBNP and moderately elevated high sensitive troponin T. HeartCore algorithm indicated elevated LVFP. As part of the evaluation of worsening of sub-clinical HF, extended laboratory tests revealed low thyroid-stimulating hormone with high free thyroxine levels indicating increased thyroid function. The endocrinologist diagnosed hyperthyroidism with multinodular goitre and prescribed thiamazole. To prevent progression to clinical HF decompensation, the dose of furosemide was increased. At 4 months, during scheduled cardiac follow-up, the patient was clinically doing well, without any signs or symptoms of HF.

Discussion: Remote monitoring devices that track pressures in the pulmonary artery require invasive implantation and are associated to potential complications. The high cost of these devices presents a significant barrier to widespread use. SEERLINQ is a novel system for remote haemodynamic monitoring based on non-invasive assessment of LVFP, presenting a promising alternative to current invasive methods.

Conclusion: This case underscores the potential benefits of this technology in the early recognition of pre-clinical deterioration and its implementation for remote home monitoring in patients with HF.

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KEYWORDS

Heart failure, telemonitoring, artificial intelligence, hyperthyroidism, photoplethysmography

LEARNING POINTS

- Untreated thyroid disorders in patients with heart failure (HF) can exacerbate signs and symptoms of HF.
- Left ventricular filling pressure (LVFP) rises 3-4 weeks before HF symptoms. Echocardiographic assessment of LVFP can be challenging in patients with atrial fibrillation or paced rhythms.
- Photoplethysmography-based analysis could be utilized to assess LVFP, enabling remote monitoring of HF patients and potentially preventing HF decompensation and hospitalization.

INTRODUCTION/BACKGROUND

Heart failure (HF) is a common clinical syndrome and is the leading cause of hospitalization for individuals over 65 years of age, with a significant risk of readmission. Preventing decompensations crucial in HF management with emphasis on identifying its underlying cause for timely and effective treatment.

Hyperthyroidism in the HF population, if left untreated, can lead to a high-output cardiac state, exacerbate signs and symptoms of HF and trigger arrhythmias. Previous research has demonstrated that left ventricular filling pressure (LVFP) generally rises progressively over weeks before leading to clinical HF decompensation and hospitalization[1]. Moreover, therapies targeting LVFP were shown to improve outcome[2]. Current monitoring devices are implanted invasively, require antithrombotic treatment, and are associated with potential complications. Additionally, strict implantation criteria, high costs, reimbursement barriers, and the need for specialized provider training limit their broader uptake in clinical practice, particularly outside HF expert canters in developed healthcare systems.

Given the limitations of invasive remote monitoring strategies and significant burden of HF, non-invasive standardized telemonitoring technologies may be of great use[3]. This case report demonstrates the potential benefits of our non-invasive LVFP monitoring device using an easily accessible photoplethysmography (PPG) signal and its clinical implications for remotely managing patients with HF.

CASE DESCRIPTION

A 99-year-old female visited an outpatient clinic for a routine cardiac check-up. Earlier that year, she had been hospitalized for acute HF in the context of pneumonia with concomitant reduction in ejection fraction to 40%. At the time of the visit, she did not complain of dyspnoea, or any other cardiovascular-related symptoms. The patient arrived in a wheelchair, accompanied by her daughter. She was able to walk only short distances independently, was oriented to place, time, and person with good contact and well-articulated and comprehensible speech.

Her medical history included permanent atrial fibrillation (AF) and a dual-chamber pacemaker implantation for sick sinus syndrome. Her chronic medications consisted of rivaroxaban 15 mg daily, furosemide 40 mg daily, metoprolol 25 mg daily, spironolactone 25 mg daily, empagliflozin 10 mg daily, and vericiguat 2.5 mg BID. Her blood pressure was 151/74 mmHg and heart rate 63 bpm. Aside from frailty, limited mobility, and elevated jugular venous distention, her physical examination was unremarkable.

Electrocardiogram showed ventricular pacing at 60 bpm with underlying AF. Transthoracic echocardiography revealed preserved left ventricular systolic function with ejection fraction of 55%, significantly enlarged left atrium, moderate mitral and tricuspid regurgitation (TR) with a TR velocity of 3.0 cm/s and normal right ventricular function. Diastolic dysfunction was present, however echocardiographic estimation of LVFP in the context of AF and ventricular pacing is inaccurate and poses a diagnostic challenge. Laboratory investigations showed significantly elevated levels of B-type natriuretic peptide terminal pro-B-type natriuretic peptide (NT-pro BNP) (3722 ng/l) and moderately elevated high-sensitive troponin T (34.6 ng/l).

LVFP were also evaluated by SEERLINQ (Seerlinq Ltd, Slovakia), a non-invasive method based on advanced artificial intelligence (AI) analysis of the photoplethysmography (PPG) signal. It requires a short measurement using a portable finger pulse oximeter, in both standing and recumbent positions, capturing a different hemodynamic response in hearts with normal and elevated LVFP. The PPG signal is further analysed by the SEERLINQ HeartCore algorithm to evaluate the patient's LVFP as normal or elevated, expressed as the diastolic reserve index (DRI). DRI is a ratio value inversely correlating to LVFP – a decline in DRI corresponds to a rise in cardiac filling pressures. For our patient, the SEERLINQ HeartCore algorithm indicated elevated LVFP. As part of the evaluation of worsening sub-clinical HF, further extended laboratory tests revealed low thyroid-stimulating hormone (0.047 mIU/l) with high free thyroxine levels indicating increased thyroid function. The patient was referred to an endocrinologist, who diagnosed hyperthyroidism with multinodular goiter and prescribed thiamazole 10 mg daily. To prevent progression to clinical HF decompensation, the furosemide dose was increased to 60 mg daily.

At 4 months, during scheduled cardiac follow-up, the patient was doing well clinically, without any signs or symptoms of HF and maintained her baseline functional status,

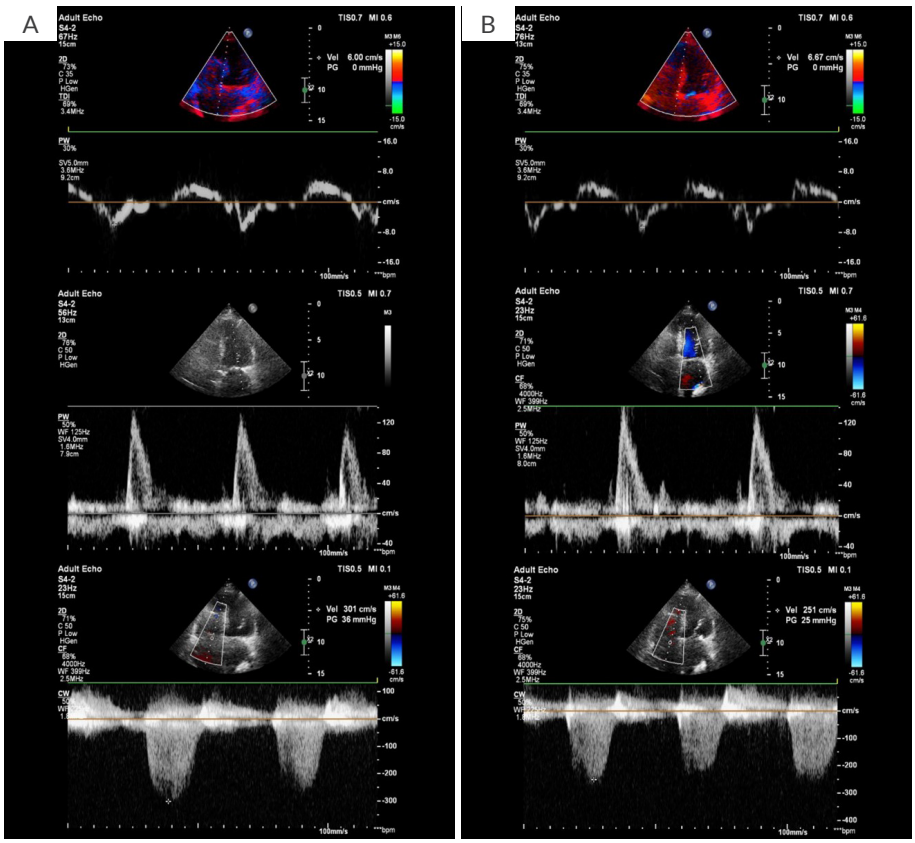


Figure 1. The change in echocardiographic parameters recorded at A) baseline visit (November 30th 2023) and at B) follow-up visit (March 21st 2024).

using a wheelchair for longer distances yet ambulating short stretches independently. Echocardiography showed improvement in parameters of diastolic function, with a drop of the TR velocity to 2.5 cm/s *(Fig. 1)*. The PPG data from the SEERLINQ HeartCore algorithm also confirmed higher DRI, correlating with down-trending of LVFP *(Fig. 2)*.

DISCUSSION

Despite significant advances in HF treatments, a substantial burden of morbidity and mortality persists, highlighting the need for improved management and follow-up of these patients. Early detection of worsening HF and treatment of various potential triggers for HF decompensation, such as hyperthyroidism, can prevent further cardiac deterioration and improve overall patient care. This is also in concordance with the 2021 European Society of Cardiology Guidelines, recommending the evaluation of thyroid function as a potential cause or exacerbating factor of HF.

Cardiac filling pressures gradually rise for 3-4 weeks before HF the onset of symptoms, decompensation and hospitalization for HF. Monitoring these pressures, coupled with a timely response, may prevent the sudden onset of HF events[1,2]. This may be particularly relevant, as in our case, for patients with advanced frailty and marked hypomobility, where the assessment of HF symptom progression and evaluation of functional capacity—as indicators of worsening HF—are significantly limited.

Right heart catheterization is the gold standard for directly measuring right-sided cardiac pressures, indirectly measuring LVFP and calculating cardiac output. While echocardiography can estimate LVFP non-invasively, this method is challenging and unreliable in various clinical settings, including AF and ventricular pacing. Moreover, neither method is suitable for home telemonitoring.

Telemonitoring of HF patients offers significant benefits in reducing mortality, personalizing treatment, minimizing hospitalizations, and improving quality of life[2]. It also enhances self-care, therapy adherence, and reduces depressive symptoms, giving patients a sense of control. For healthcare systems, remote monitoring reduces

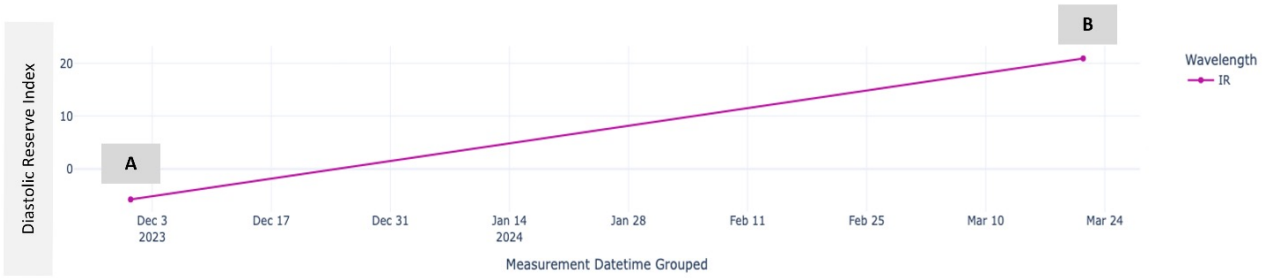


Figure 2. The change in diastolic reserve index (DRI) recorded at A) baseline visit (November 30th 2023) and at B) follow-up visit (March 21st 2024). DRI is a ratio value inversely to left ventricular filling pressure – a rise in DRI corresponds to a decline in cardiac filling pressures.

costs, alleviates system overload, improves efficiency, and strengthens e-health capabilities.

Initially, early telemonitoring methods based on tracking symptoms, weight and vital signs, failed to show significant benefit in larger randomized trials[4,5], while haemodynamic-based approach for tracking cardiac filling pressures with implantable monitors, such as The CardioMEMS - a wireless sensor for monitoring pulmonary artery pressures, has demonstrated improvement in quality of life, survival and reduction in HF hospitalizations[6].

On the other hand, remote monitoring devices that track pressures in the pulmonary artery require invasive implantation. Potential complications include bleeding, hematomas, haemoptysis, infections, allergic reactions, arrhythmias, embolism, myocardial infarction, cardiac perforation, stroke, transient ischemic attack, and death. Post-implantation, patients must take dual antiplatelet therapy for 1 to 3 months, followed by lifelong acetylsalicylic acid therapy, which may not be feasible for all HF patients. Additionally, the high cost of these devices presents a significant barrier to widespread use.

SEERLINQ is a novel system for remote haemodynamic monitoring based on non-invasive assessment of LVFP, presenting a promising alternative to current invasive methods. This system is based on advanced AI analysis of the PPG signal which can be measured by any smart device such as smartwatches, fitness bands and even smartphone cameras, enhancing its potential scalability and widespread uptake[7]. The system is currently utilized in a telemonitoring program, run by Seerlinq in collaboration with hospitals and cardiology practitioners in Slovakia, with over 300 actively enrolled heart failure patients, demonstrating its real-world feasibility and clinical applicability.

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