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CASE SERIES
Heart failure

Novel findings of respiratory rate increases using the multisensor HeartLogic heart failure monitoring algorithm in COVID-19-positive patients: a case series

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Background With the ongoing coronavirus disease 2019 (COVID-19) epidemic, remote monitoring of patients with implanted cardiac devices has become more important than ever, as physical distancing measures have placed limits on in-clinic device monitoring. Remote monitoring alerts, particularly those associated with heart failure trends, have proved useful in guiding care in regard to monitoring fluid status and adjusting heart failure medications.

Case summary This report describes use of Boston Scientific's HeartLogic algorithm, which is a multisensor device algorithm in implantable cardioverter-defibrillator devices that is proven to be an early predictor of heart failure decompensation by measuring several variables, including respiratory rate, nighttime heart rate, and heart sounds. We present three cases of patients who were actively surveilled by the various HeartLogic device algorithm sensors and were identified to have increasing respiratory rates high enough to trigger a HeartLogic alert prior to a positive COVID-19 diagnosis.

Discussion We propose that the HeartLogic algorithm and its accompanying individual physiologic sensors demonstrate potential for use in identifying non-heart failure-related decompensation, such as COVID-19-positive diagnoses.

Keywords COVID-19 • HeartLogic • Heart failure • Remote monitoring respiratory sensor • Case series

Learning points

- To appreciate the role that respiratory rate rises before the clinical diagnosis of coronavirus disease 2019 (COVID-19), which allows the potential use of remote monitoring devices to provide remote care for heart failure patients during the COVID-19 pandemic.
- To recognize how traditional heart failure trends can help to identify non-heart failure-related decompensation, including COVID-19, in patients.

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Introduction

In the wake of the coronavirus disease 2019 (COVID-19) pandemic, we have recognized the utility in remote monitoring technologies that are available to improve surveillance of patients with cardiac devices who are at a higher risk for morbidity and mortality, such as those with heart failure.[1] Stay-at-home orders and physical distancing mandates have led to at least temporary reductions in clinic and hospital visits, reducing opportunities for patient in-person exams.[2,3] Through the use of telehealth visits and remote monitoring, clinicians can implement therapeutic interventions sooner and reduce hospitalizations for decompensated heart failure.[4] Various device manufacturers have proprietary algorithms for monitoring heart failure, including the HeartLogic Index from Boston Scientific.[5] Boston Scientific has incorporated multiple sensors within their implantable cardioverter-defibrillators (ICDs) and cardiac resynchronization therapy defibrillators. The following physiologic parameters can be utilized individually or, when combined, as an algorithm for monitoring heart failure status: (i) S1 and S3 heart sounds; (ii) thoracic impedance; (iii) heart rate; (iv) respiration rate, including its ratio to tidal volume; and (v) patient activity (*Table 1*).[5] The HeartLogic index algorithm generates a composite number or score and triggers an alert through its home monitoring system when the score crosses a threshold of 16, as this score serves as a signal that the patient is at high risk for a heart failure event or exacerbation. This score is recalculated daily and continues to alert weekly until the score has fallen below the threshold of 6, indicating that the contributing trends have improved. What has not yet been studied, given the novelty of COVID-19, is whether these various components or contributing trends within this algorithm can be used to identify non-heart failure-related decompensation, such as alerts for an increased respiratory rate in helping to diagnose COVID-19-positive patients.

Table 1 A review of the HeartLogic heart failure index physiologic parameters

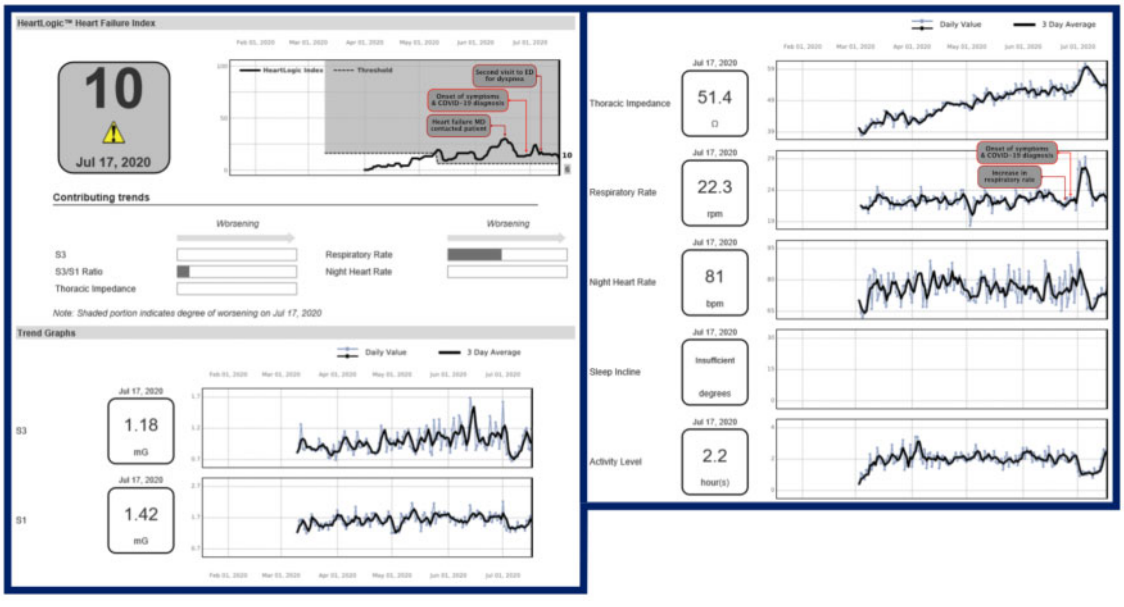
HeartLogic sensor variable	Clinical relevance	Directional change concerning for worsening HF
S1	Indicator of ventricular contraction	Decline
S3	Indicator of early ventricular diastolic filling. Surrogate of decreased left ventricular contractility	Elevation
Respiratory rate	Ratio of respiration to tidal volume. Surrogate of rapid shallow breathing, i.e. dyspnoea	Elevation
Thoracic impedance	Surrogate of lung fluid accumulation	Decline
Activity level	Reflection of functional status	Decline

Case presentations

Case 1

A 67-year-old woman with a left ventricular assist device (LVAD) *in situ* for non-ischaemic cardiomyopathy, single-chamber ICD, atrial fibrillation, left ventricular ejection fraction (LVEF) of 20%, moderately depressed right ventricular function, and on cardiac medications, including spironolactone 25 mg daily, furosemide 20 mg daily as needed, lisinopril 5 mg daily, and potassium chloride 20 MEQ daily as

Timeline



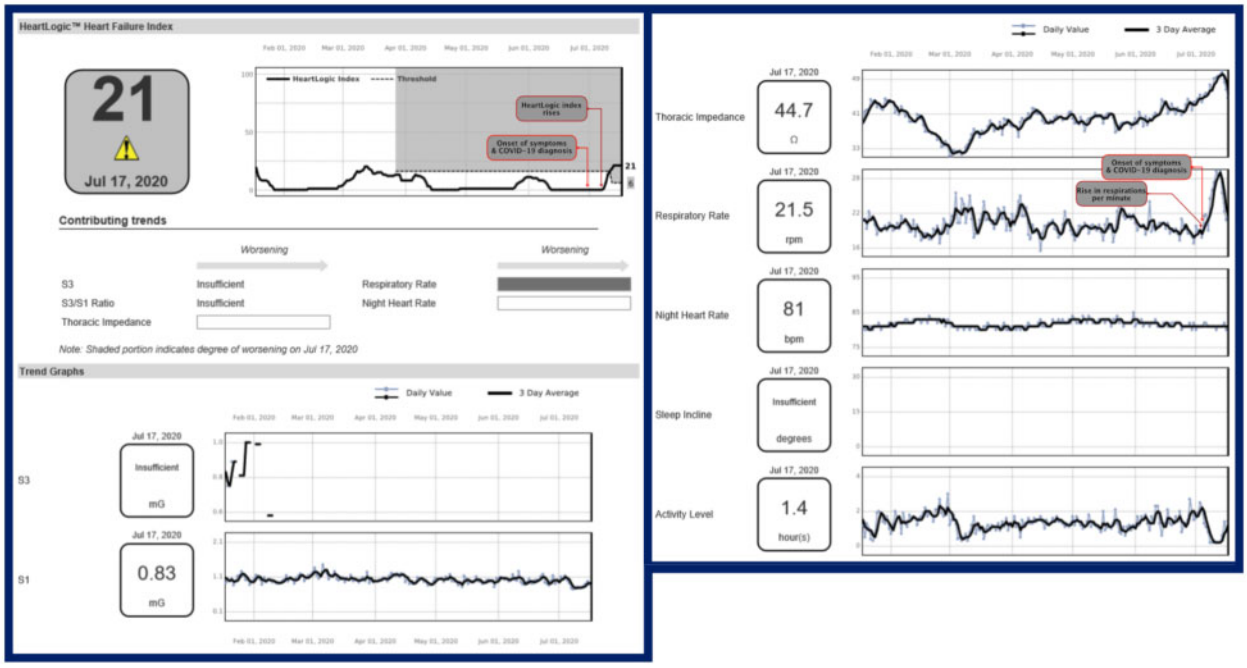


Figure 1 Left ventricular assist device patient positive for COVID-19.

needed, notified her primary LVAD team on 6 July 2020 that everyone in her household had tested positive for COVID-19 and that she had developed a fever, cough, dyspnoea on exertion, and vomiting. She was instructed to present to the local emergency department for COVID-19 testing, at which time she did test positive for COVID-19. Her HeartLogic index began rising on 8 July 2020, and the only contributing trend causing the rise was an increasing respiratory rate. She reached the HeartLogic alert threshold of 16 on 11 July 2020, and her increased respiratory rate was still the only contributing trend for the rising HeartLogic index. Review of her respiratory rate trend revealed an increase in respirations per minute beginning on 4 July 2020. As of 17 July 2020, her HeartLogic index score remained elevated at 21, with respiratory rate continuing to show worsening trends (*Figure 1*). Notably, the relationship between rise in respiratory rate and COVID-19 diagnosis was only made in retrospect, thus the medical team was not alerted to the changes. The patient had already received the diagnosis of COVID-19 at the time when the actual HeartLogic (multisensor) threshold crossed into the abnormal range. Continued monitoring of her HeartLogic score allowed for remote monitoring and regular phone calls to the patient to assess symptomatology of COVID-19. To date, the patient was able to avoid a hospitalization, and no changes to her cardiac medications were necessary.

Case 2

A 31-year-old woman with non-ischaemic cardiomyopathy, hypertension, single-chamber ICD, Type 2 diabetes mellitus, LVEF of 30%, normal right ventricular function, and on cardiac medications, including sacubitril-valsartan 97–103 mg daily, spironolactone 25 mg daily, hydralazine 10 mg daily, carvedilol 25 mg twice daily, and bumetanide 1 mg twice daily, originally alerted for elevated HeartLogic index on 10 May 2020, with a primary contributing trend of S3 heart sound and S3/S1 ratio. She had a telemedicine visit with her heart failure physician on 11 May 2020, and the patient admitted to poor medication compliance. She was encouraged to take medications as prescribed and reduce salt intake, and the patient reported commitment to these changes. She declined a clinic visit for labs at that time due to fear of COVID-19. She was contacted by a heart failure physician again in mid-June 2020 because she remained in HeartLogic alert status with an increase in respiratory rate but decreasing S3 and S13/S1 ratio, and the patient denied any symptoms at that time. On June 29, the patient presented to an outside emergency department with new-onset chest pain, dyspnoea, and cough. Chest X-ray demonstrated no overt focal oedema or focal airspace consolidation. Of note, her N-terminal pro brain natriuretic peptide during that visit was 111 pg/mL, which is significantly lower than her baseline of 350–400 pg/mL. Serial troponins were negative, and D-dimer was <200. Her temperature was 99.4°C, O_2 saturation was 99%, and her physical exam was normal, including auscultation of breath sounds. She was discharged with cough medication. Her COVID-19 test resulted as positive after discharge, and she was notified by the emergency room provider. On 6 July 2020, she contacted her primary care provider regarding her ongoing cough and requested additional cough medication. She was instructed to present to the emergency department due to concern for unimproved respiratory symptoms in the setting of COVID-19. As of 16 July 2020, her HeartLogic index remains in alert status with a score of 14 and with respiratory rate being the primary contributing trend (*Figure 2*). Regular surveillance of her HeartLogic trends is ongoing by her heart failure team. No changes to her cardiac medications were required.

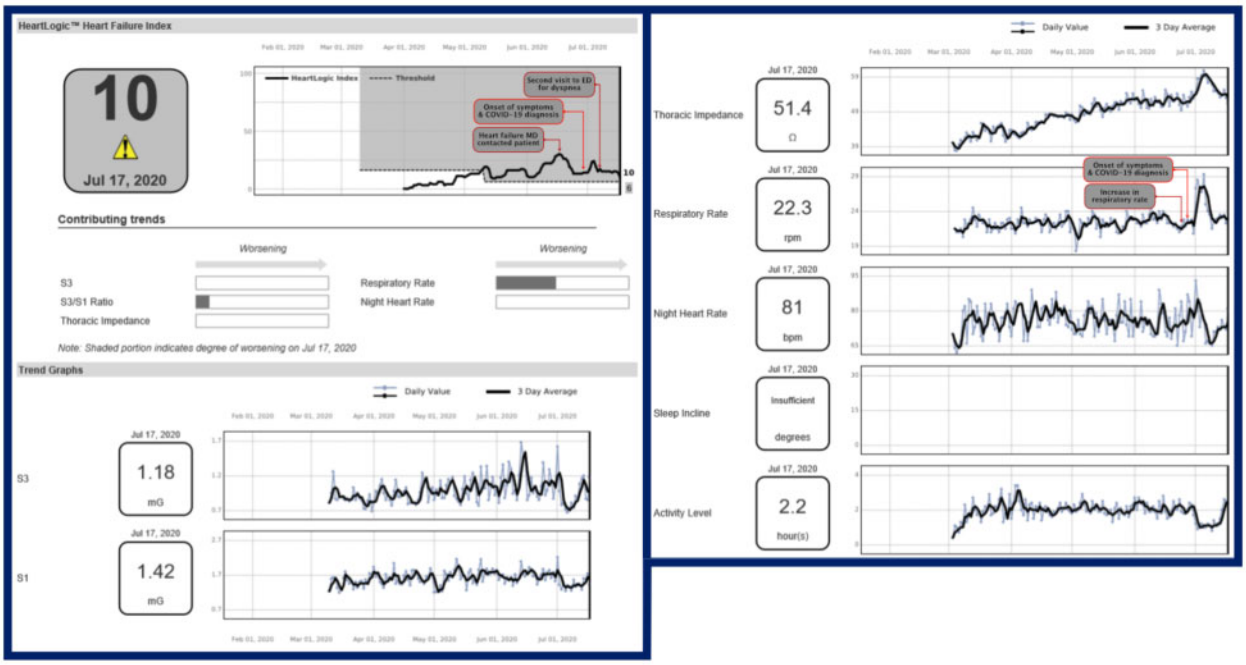


Figure 2 Non-ischaemic cardiomyopathy patient with HeartLogic alert positive for COVID-19.

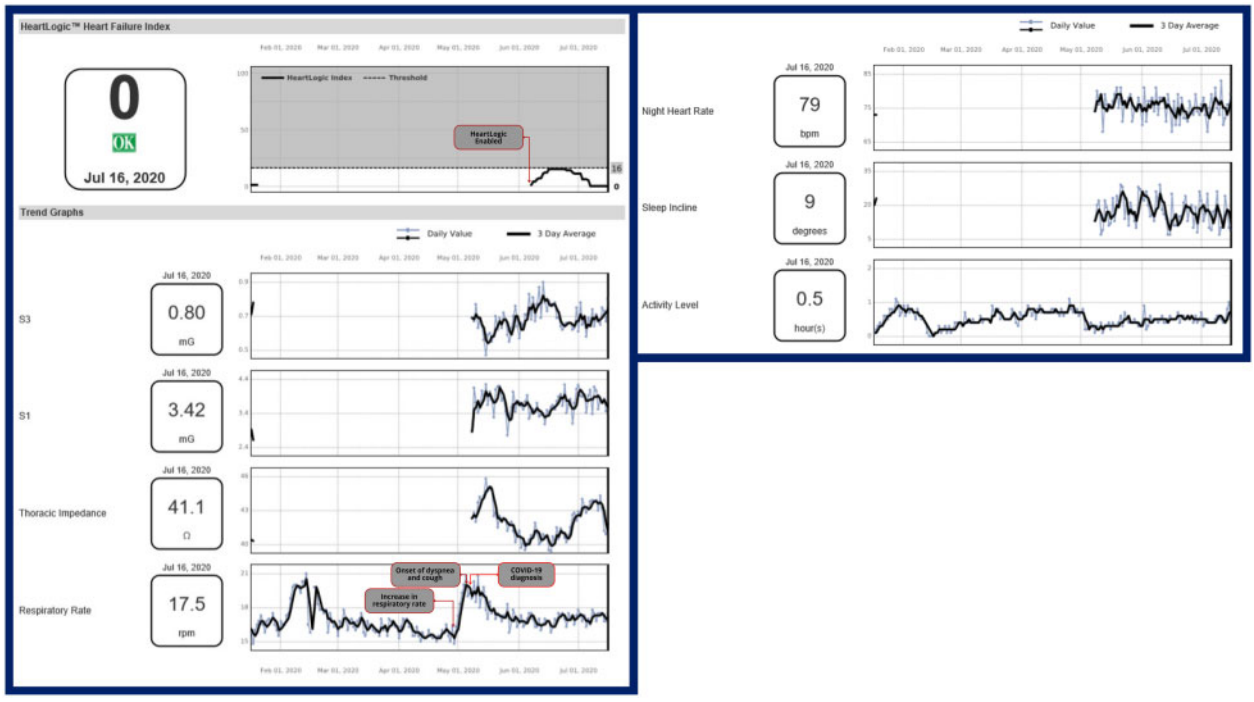


Figure 3 Ischaemic cardiomyopathy patient in skilled nursing facility positive for COVID-19.

Case 3

An 84-year-old man with ischaemic cardiomyopathy, complete heart block, biventricular defibrillator, coronary artery disease, aortic stenosis, Type 2 diabetes mellitus, LVEF of 30%, normal right ventricular function, and on cardiac medications, including lisinopril 10 mg daily, furosemide 40 mg daily, and carvedilol 12.5 mg twice daily, residing in a skilled nursing facility, developed dyspnoea and cough on 1 May 2020. His HeartLogic Index did not reach alert status, but his respiratory rate trend was active and demonstrated a rise from 14.8 respirations per minute on 29 April 2020 to 20.8 respirations per minute on 5 May 2020 (*Figure 3*). Based on his symptoms and other positive cases within the facility, he was moved to the COVID-19 unit while waiting for his COVID test results. He received a positive test result on 7 May 2020, indicating that his respiratory rate trend preceded his positive COVID-19 diagnosis. The relationship between the respiratory trend and COVID-19 diagnosis was established in retrospect and medical decisions were not made based on our findings. No changes to his cardiac medications were required.

Discussion

While COVID-19 is often asymptomatic, it is more deadly in patients with cardiovascular disease, especially heart failure.[1] The European Society of Heart Failure Guidelines already support the use of remote monitoring devices in improving clinical outcomes,[6] and remote monitoring technology could prove especially valuable to detect vital sign changes, such as respiratory rate, when the patient is asymptomatic and before a diagnosis of COVID-19 is made. We reviewed three cases in which the respiratory rate sensor within the HeartLogic algorithm demonstrated elevations in respirations per minute days before COVID-19 diagnoses. In the first case, the HeartLogic algorithm alerted for increased respiratory rate in a patient who was confirmed to be COVID-19-positive after rising for several days. Respiratory rate alone changed enough from baseline to cross the HeartLogic threshold and was used subsequently to monitor recovery. In the second case, HeartLogic demonstrated that the specific sensors within the algorithm changed throughout a span of 2 months as the patient's health changed, initially due to lack of medication compliance. When the respiratory rate sensor became the predominant factor in maintaining HeartLogic alert status, this prompted further workup and led to the eventual diagnosis of COVID-19, highlighting the significance in identifying which specific sensor trends are worsening so as to treat appropriately. The third patient did not have HeartLogic activated at the time of his COVID-19 diagnosis, but his individual respiratory rate sensor was active and rising, leading his heart failure providers to consider the possibility of COVID-19 infection, even before his symptoms worsened enough to prompt his nursing home to take action.

The HeartLogic multisensor algorithm was tested and validated to identify early signs of worsening heart failure status and decrease hospitalizations when appropriate therapy is delivered in response to the changing trends.[7] This algorithm can be used for more than just optimizing heart failure medications. These three cases demonstrate that individual sensors within the algorithm may help identify patients who are COVID-19-positive based on increasing respiratory rate, even before patients themselves report symptoms. Other sensor data that is incorporated into the HeartLogic algorithm, such as a decline in activity, may be used in conjunction with an increased respiratory rate to identify patients who are COVID-positive. Rising heart rate trends may be an indicator that a patient is febrile, and increasing sleep incline may be used to identify those patients who are developing orthopnoea, which is also included in COVID-19 symptomatology. These sensors may prove useful in recognizing changing health status in patients that could lead to a positive COVID-19 diagnosis, all while having the data delivered remotely and without the risk of exposing patients or providers to the unnecessary risks that are inherent to clinic visits during the COVID-19 pandemic. Notably, other implanted device technologies have their respective sensor algorithms. For example, Medtronic devices track a change in thoracic impedance (OptiVol), and a change in this sensor has been found to independently track with COVID-19 pneumonias.[8] While HeartLogic and other implanted diagnostic device algorithms have been well-correlated with the ability to diagnose heart failure decompensation,[9] the evidence for the ability to detect non-heart failure events are limited. Furthermore, there is no prospective evidence yet to suggest that acting upon device algorithms such as HeartLogic improves outcomes, but such efforts are ongoing. Importantly, remote management of patients, even if supported by multisensor technology, can be insufficient to manage complex patients as in the presented cases. Two ongoing prospective studies are evaluating the impact of the HeartLogic algorithm on clinical outcomes as part of a registry [Precision Event Monitoring for Patients With Heart Failure Using HeartLogic (PREEMPT-HF, clinicaltrials.gov #NCT03579641)] and a randomized clinical trial [Multiple Cardiac Sensors for the Management of Heart Failure (MANAGE-HF, clinicaltrials.gov #NCT03237858)].

Conclusion

Optimization of care in patients with implanted cardiac devices through remote monitoring is not a new concept, but the COVID-19 pandemic has underscored the value of this by helping to reduce clinic visits and reinforce physical distancing recommendations through the use of telehealth visits in place of in-person clinic visits. Heart failure monitoring through the HeartLogic algorithm has led us to discover that both individual sensors and HeartLogic index scores can help to identify COVID-19-positive patients, often before patients report symptoms. We believe that further evaluation of other implanted cardiac devices with vital sign sensors (e.g. respiratory rate and heart rate) will lead us to discover more COVID-19-positive patients based on changes in those sensor trends. We propose the development of a registry of all HeartLogic patients who are COVID-19-positive to better determine more specific timelines related to changes in respiratory rate and COVID-19 diagnoses.

Lead author biography

Andrea Rebecca Yapejian is a cardiac electrophysiology nurse practitioner at Duke University Hospital. She completed her Master of Science in Nursing degree at Duke University and her Bachelor of Science in Nursing degree at Queens University of Charlotte. She also holds a Bachelor of Science degree in Business Information Systems and Computer Science from Charleston Southern University. Her fields of interest include cardiac implanted electronic devices, remote monitoring, and the use of both for heart failure management. Follow her on twitter @ryapejianFNP.

Supplementary material

Supplementary material is available at *European Heart Journal - Case Reports* online.

Slide sets: A fully edited slide set detailing this case and suitable for local presentation is available online as Supplementary data.

Consent: The authors confirm that witnessed verbal consent for submission and publication of this case report, including images and associated text, has been obtained from the patients detailed in this case report via telephone. This has been discussed with the editors.

Conflict of interest: None declared.

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