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ORIGINAL ARTICLE

Performance of a multisensor implantable defibrillator algorithm for heart failure monitoring related to co-morbidities

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Abstract

Aims The HeartLogic algorithm combines multiple implantable defibrillator (ICD) sensor data and has proved to be a sensitive and timely predictor of impending heart failure (HF) decompensation in cardiac resynchronization therapy (CRT-D) patients. We evaluated the performance of this algorithm in non-CRT ICD patients and in the presence of co-morbidities.

Methods and results The HeartLogic feature was activated in 568 ICD patients (410 with CRT-D) from 26 centres. The median follow-up was 26 months [25th–75th percentile: 16–37]. During follow-up, 97 hospitalizations were reported (53 cardiovascular) and 55 patients died. We recorded 1200 HeartLogic alerts in 370 patients. Overall, the time IN the alert state was 13% of the total observation period. The rate of cardiovascular hospitalizations or death was 0.48/patient-year (95% CI: 0.37–0.60) with the HeartLogic IN the alert state and 0.04/patient-year (95% CI: 0.03–0.05) OUT of the alert state, with an incidence rate ratio of 13.35 (95% CI: 8.83–20.51, $P < 0.001$). Among patient characteristics, atrial fibrillation (AF) on implantation (HR: 1.62, 95% CI: 1.27–2.07, $P < 0.001$) and chronic kidney disease (CKD) (HR: 1.53, 95% CI: 1.21–1.93, $P < 0.001$) independently predicted alerts. HeartLogic alerts were not associated with CRT-D versus ICD implantation (HR: 1.03, 95% CI: 0.82–1.30, $P = 0.775$). Comparisons of the clinical event rates in the IN alert state with those in the OUT of alert state yielded incidence rate ratios ranging from 9.72 to 14.54 (all $P < 0.001$) in all groups of patients stratified by: CRT-D/ICD, AF/non-AF, and CKD/non-CKD. After multivariate correction, the occurrence of alerts was associated with cardiovascular hospitalization or death (HR: 1.92, 95% CI: 1.05–3.51, $P = 0.036$).

Conclusions The burden of HeartLogic alerts was similar between CRT-D and ICD patients, while patients with AF and CKD seemed more exposed to alerts. Nonetheless, the ability of the HeartLogic algorithm to identify periods of significantly increased risk of clinical events was confirmed, regardless of the type of device and the presence of AF or CKD.

Keywords Atrial fibrillation; Chronic kidney disease; CRT; Heart failure; ICD; Risk stratification

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Clinical Trial Registration: URL: http://clinicaltrials.gov/Identifier: NCT02275637.

Introduction

Implantable cardioverter defibrillators (ICD) and defibrillators for resynchronization therapy (cardiac resynchronization therapy defibrillator [CRT-D]) are widely adopted for the management of chronic heart failure (HF).[1,2,3] Some modern ICDs are equipped with automated algorithms that provide detailed information on the HF condition on a daily basis. Many studies have investigated the ability of ICD diagnostics to identify patients at risk of HF events, with contradictory results.[4,5,6,7] In the past decade, studies have reported combining ICD diagnostics in order to better stratify and manage patients at risk of HF events.[8,9,10] In the Multisensor Chronic Evaluation in Ambulatory Heart Failure Patients (MultiSENSE) study,[11] a novel algorithm for HF monitoring was implemented: the HeartLogic (Boston Scientific, St. Paul, Minnesota) Index, which combines physiological data from multiple ICD-based sensors. The index enabled dynamic assessment of HF, identifying periods when patients were at significantly increased risk of worsening HF.[12] However, the algorithm was developed only on the basis of data from CRT-D patients, and there are no data on its performance in the presence of cardiovascular and non-cardiovascular co-morbidities, which are common in HF patients and are known to affect disease severity and prognosis. In the present study, we sought to evaluate the incidence of HeartLogic alerts in patients who received either CRT-D or ICD, and to investigate the impact of co-morbidities on the frequency of alerts and on the risk stratification ability of the algorithm.

Methods

Patient selection

The study was a prospective, non-randomized, multicentre evaluation of patients who had received an ICD or cardiac resynchronization therapy ICD (CRT-D) endowed with the HeartLogic™ diagnostic algorithm. Consecutive HF patients with reduced left ventricular ejection fraction (≤35% at the time of implantation) who had received a device in accordance with standard indications[1] and were enrolled in the LATITUDE (Boston Scientific) remote monitoring platform were included at 26 study centres (full list of participating centres is in Data S1) and followed up in accordance with the standard practice of the participating centres. Clinics periodically checked the remote monitoring website for transmissions. Moreover, remote data reviews and patient phone contacts were undertaken at the time of HeartLogic alerts, to assess the patient's decompensation status and, if possible, to prevent further worsening. However, the study protocol did not mandate any specific intervention algorithm and physicians were free to remotely implement clinical actions, or to schedule extra in-office visits when deemed necessary. Data on the clinical events that occurred during follow-up were collected at the study centres within the framework of a prospective registry (ClinicalTrials.gov identifier: NCT02275637). The Institutional Review Boards approved the study, and all patients provided written informed consent for data storage and analysis.

Device characteristics

Commercially available ICD/CRT-Ds equipped with the HeartLogic™ diagnostic feature and standard transvenous leads were used in this study. The details of the HeartLogic algorithm have been reported previously.[11] Briefly, the algorithm combines data from multiple sensors: accelerometer-based first and third heart sounds, intrathoracic impedance, respiration rate, the ratio of respiration rate to tidal volume, night heart rate, and patient activity. Each day, the device calculates the degree of worsening in sensors from their moving baseline and computes a composite index. An alert is issued when the index crosses a programmable threshold (nominal value, 16). When the index enters an alert state, the 'exit-alert' threshold is automatically dropped to a recovery value (nominal value, 6).

Study endpoints

The objectives of the present analysis were to compare the incidence of HeartLogic alerts between CRT and non-CRT patients, and to evaluate their frequency in relation to the presence of co-morbidities. HeartLogic index values >16 identified periods as IN an alert state versus OUT of an alert state. We also investigated the impact of the presence of co-morbidities on the performance of the HeartLogic Index in detecting follow-up periods of significantly increased risk of clinical events. The study endpoints consisted of cardiovascular hospitalizations requiring at least one overnight stay and the combination of cardiovascular hospitalizations and death.

Statistical analysis

Quantitative variables are reported as means±SD if normally distributed, or medians with 25th to 75th percentiles in the case of skewed distribution. Normality of distribution was tested by means of the nonparametric Kolmogorov–Smirnov test. Categorical data are expressed as percentages. Differences between mean data were compared by means of a *t*-test for Gaussian variables, and Mann–Whitney or Wilcoxon non-parametric test for non-Gaussian variables, respectively, for independent or paired samples. Differences in proportions were compared by means of χ^2 analysis. Clinical event

rates were calculated separately during IN and OUT alert states in terms of the ratio between the total count of events occurring in each state and the respective patient follow-up durations, and were expressed as events per patient-year. Analysis of the time to the first event was made by means of the Kaplan–Meier method. Cox proportional hazards models were used to determine the association between patients' baseline characteristics and the occurrence of events during the follow-up period, and to estimate the hazard ratios (HRs) and the 95% confidence intervals (CIs) of an episode. Additionally, the sensitivity (with 95% CI) for detecting cardiovascular hospitalizations and the combined endpoint of hospitalization or death were also computed by classifying alerts as true-positive if the alert onset occurred and did not reset before an endpoint. Moreover, the false-positive rate was defined as the ratio of the total number of alerts that were not true-positive alerts over the total usable follow-up duration. All variables displaying statistical significance (P-value <0.05) were entered into a multivariate regression analysis. The time course of HeartLogic index and sensor changes surrounding the alert were evaluated at two timepoints.[13] A 30-day baseline (average calculated 30 days prior to the alert) was compared with the alert state (weekly average calculated from the alert day to day 6). Sensor data were compared between different temporal periods by means of a paired t-test. A P value <0.05 was considered significant for all tests. All statistical analyses were performed by means of R: a language and environment for statistical computing (R Foundation for Statistical Computing, Vienna, Austria).

Results

Study population

From December 2017 to June 2021, HeartLogic was activated in 568 patients who had received an ICD (n = 158) or CRT-D (n = 410). The index threshold was programmed to the nominal value of 16 in all patients and was not modified during follow-up. *Table 1* shows the baseline clinical variables of all patients in the present analysis.

Follow-up

The median follow-up was 26 months [25th–75th percentile: 16–37]. During the observation period, 97 hospitalizations were reported (53 for cardiovascular reasons) and 55 patients died. The HeartLogic index crossed the threshold value 1200 times (0.71 alerts/patient-year) in 370 patients. The time in the IN-alert state was 13% of the total observation period in the overall population and 20% of the follow-up period of the 370 patients with alerts. *Table 1* shows the clinical variables of patients stratified by time in the IN-alert state (no alerts, <20%, ≥20%).

Association between HeartLogic alerts and baseline variables

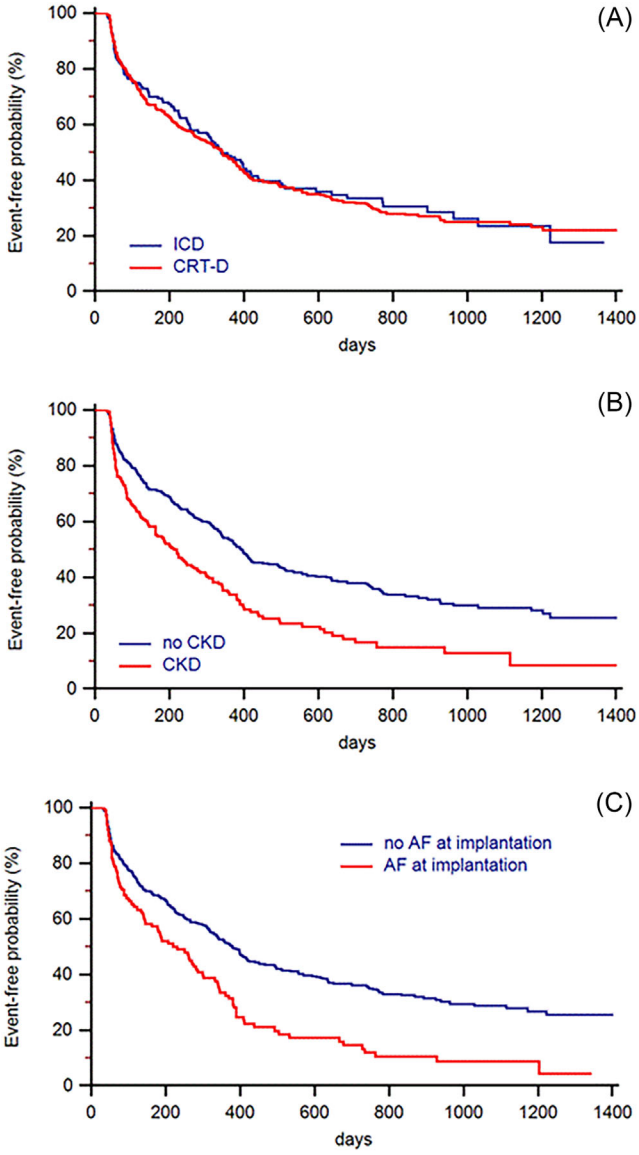
Figure 1 shows the Kaplan–Meier analysis of time from implantation to the first HeartLogic alert in patients with CRT-D and ICD (HR: 1.03, 95% CI: 0.82–1.30; P = 0.775). The results of the regression analysis of variables associated with alert occurrence are shown in *Table 2*. Among patient

Table 1 Demographics and baseline clinical parameters of the study population

Parameter	Total (N = 568)	No alerts (N = 198)	Time in alert <20% (N = 219)	Time in alert ≥20% (N = 151)
Male gender, n (%)	453 (80)	158 (80)	171 (78)	124 (82)
Age, years	69 ± 10	68 ± 9	69 ± 10	71 ± 11*
Ischaemic aetiology, n (%)	285 (50)	95 (48)	103 (47)	87 (58)#
NYHA class				#
Class I, n (%)	36 (6)	16 (8)	16 (7)	4 (3)
Class II, n (%)	351 (62)	126 (64)	131 (60)	94 (62)
Class III, n (%)	171 (30)	52 (26)	71 (32)	48 (32)
Class IV, n (%)	10 (2)	4 (2)	1 (0.5)	5 (3)
LV ejection fraction, %	32 ± 9	33 ± 9	32 ± 9	30 ± 8
AF history, n (%)	196 (35)	38 (19)	78 (36)*	80 (53)*#
AF on implantation, n (%)	100 (18)	14 (7)	42 (19)*	44 (29)*#
Diabetes, n (%)	167 (29)	52 (26)	71 (32)	44 (29)
COPD, n (%)	89 (16)	29 (15)	32 (15)	28 (19)
Chronic kidney disease,[$] n (%)	153 (27)	33 (17)	63 (29)*	57 (38)*
Hypertension, n (%)	334 (59)	118 (60)	128 (58)	88 (58)
Beta-blocker use, n (%)	520 (92)	185 (93)	196 (89)	139 (92)
ACE-I, ARB or ARNI use, n (%)	536 (94)	186 (94)	211 (96)	139 (92)
Diuretic use, n (%)	506 (89)	167 (84)	193 (88)	146 (97)*#
Antiarrhythmic use, n (%)	116 (20)	22 (11)	49 (22)*	45 (30)*
CRT device, n (%)	410 (72)	137 (69)	162 (74)	111 (74)
Primary prevention, n (%)	500 (88)	181 (91)	187 (85)	132 (87)

Patients are stratified according to the percentage of time in alert during follow-up.
ACE, angiotensin-converting enzyme; AF, atrial fibrillation; ARB, angiotensin II receptor blockers; ARNI, angiotensin receptor-neprilysin inhibitor; COPD, chronic obstructive pulmonary disease; CRT, cardiac resynchronization therapy; LV, left ventricular; NYHA, New York Heart Association.
*$P < 0.05$ versus no alerts.
#$P < 0.05$ versus <20%.
[$]Estimated glomerular filtration rate <60 mL/min/1.73 m^2.

Figure 1 Kaplan–Meier analysis of time to first HeartLogic alert. Patients are stratified according to device type (CRT-D: HR: 1.03, 95% CI: 0.82–1.30; $P = 0.775$) (A), chronic kidney disease at baseline (HR: 1.71; 95% CI: 1.33–2.18; $P < 0.001$) (B), and atrial fibrillation on implantation (HR: 1.77, 95% CI: 1.33–2.37; $P < 0.001$) (C).



characteristics, chronic kidney disease (CKD) (HR: 1.53, 95% CI: 1.21–1.93, $P < 0.001$) and atrial fibrillation (AF) on implantation (HR: 1.62, 95% CI: 1.27–2.07, $P < 0.001$) independently predicted alerts. The Kaplan–Meier plot of the time to the first alert in patients stratified according to CKD and AF on implantation is shown in *Figure 1*.

Risk stratification of clinical events

Thirty-five cardiovascular hospitalizations and 37 deaths were associated with the HeartLogic IN alert state, whereas the remaining 18 cardiovascular hospitalizations and 18 deaths occurred in the OUT of alert state. The rates of cardiovascular hospitalizations and those of the combined endpoints of cardiovascular hospitalization or death are reported in *Table 3*, for the overall population and for the groups of patients stratified by device type, presence of CKD and AF on implantation. Comparisons of the event rates in the IN alert state with those in the OUT of alert state yielded incidence rate ratios ranging from 7.36 to 13.14 for cardiovascular hospitalizations and from 9.72 to 14.54 for the combined endpoint of hospitalization or death in all groups of patients (all $P < 0.001$). The sensitivity for detecting study endpoints and the false-positive rate for all patients and all subgroups of patients is reported in *Table S1*. After multivariate

Table 2 Univariate and multivariate analysis of baseline variables associated with HeartLogic alert

	Univariate analysis			Multivariate analysis		
	HR	95% CI	*P*	HR	95% CI	*P*
Age	1.02	1.00–1.03	0.006	1.01	0.99–1.02	0.210
Male gender	0.89	0.69–1.15	0.368	-	-	-
NYHA class	1.08	0.91–1.27	0.405	-	-	-
Ischaemic heart disease	1.23	1.00–1.51	0.047	1.06	0.85–1.32	0.589
Ejection fraction	0.99	0.98–1.01	0.242	-	-	-
History of AF	1.81	1.47–2.22	<0.001	-	-	-
AF on implantation	1.78	1.40–2.27	<0.001	1.62	1.27–2.07	<0.001
Hypertension	0.97	0.79–1.19	0.766	-	-	-
Pulmonary disease	1.09	0.82–1.43	0.563	-	-	-
Diabetes	1.15	0.93–1.43	0.214	-	-	-
Chronic kidney disease	1.72	1.38–2.14	<0.001	1.53	1.21–1.93	<0.001
CRT device	1.03	0.82–1.30	0.775	-	-	-

AF, atrial fibrillation; NYHA, New York Heart Association.

Table 3 Comparison of clinical event rates in the IN alert state with those in the OUT of alert state and incidence rate ratios (IRR)

	Cardiovascular hospitalizations			Cardiovascular hospitalizations or death		
	IN alert state	OUT alert state	IRR (95% CI)	IN alert state	OUT alert state	IRR (95% CI)
All patients (*N* = 568)	0.23 (0.16–0.32)	0.02 (0.01–0.03)	12.98 (7.16–24.35)	0.48 (0.37–0.60)	0.04 (0.03–0.05)	13.35 (8.83–20.51)
CRT-D (*N* = 410)	0.20 (0.13–0.30)	0.02 (0.01–0.03)	12.86 (6.14–28.36)	0.46 (0.34–0.60)	0.03 (0.02–0.05)	14.54 (8.80–24.66)
ICD (*N* = 158)	0.32 (0.17–0.57)	0.02 (0.01–0.05)	13.14 (4.56–42.65)	0.54 (0.33–0.83)	0.05 (0.03–0.09)	10.95 (5.096–24.56)
CKD (*N* = 153)	0.44 (0.28–0.65)	0.04 (0.02–0.07)	10.82 (5.00–25.36)	0.82 (0.60–1.09)	0.06 (0.03–0.09)	14.49 (7.81–28.59)
Non-CKD (*N* = 415)	0.11 (0.06–0.21)	0.01 (0.01–0.02)	10.89 (3.99–31.17)	0.28 (0.19–0.41)	0.03 (0.02–0.04)	9.72 (5.33–17.90)
AF (*N* = 100)	0.62 (0.40–0.89)	0.08 (0.04–0.14)	7.36 (3.78–14.89)	0.95 (0.69–1.29)	0.09 (0.06–0.15)	10.11 (5.63–18.94)
Non-AF (*N* = 468)	0.21 (0.13–0.31)	0.02 (0.01–0.03)	10.64 (5.34–21.67)	0.28 (0.19–0.40)	0.02 (0.01–0.04)	12.22 (6.66–22.97)

$P < 0.001$ for all patients and all subgroups of patients.

correction for CKD and AF on implantation, the occurrence of at least one HeartLogic alert was associated with the occurrence of cardiovascular hospitalizations (HR: 3.44, 95% CI: 1.22–9.76, $P = 0.021$) and with the combined endpoint of cardiovascular hospitalization or death (HR: 1.92, 95% CI: 1.05–3.51, $P = 0.036$) (*Figure 2*). Additionally, a time IN alert ≥20% was associated with cardiovascular hospitalizations (HR: 4.14, 95% CI: 2.20–7.79, $P < 0.001$) and with cardiovascular hospitalization or death (HR: 3.83, 95% CI: 2.45–5.98, $P < 0.001$).

Sensor data findings

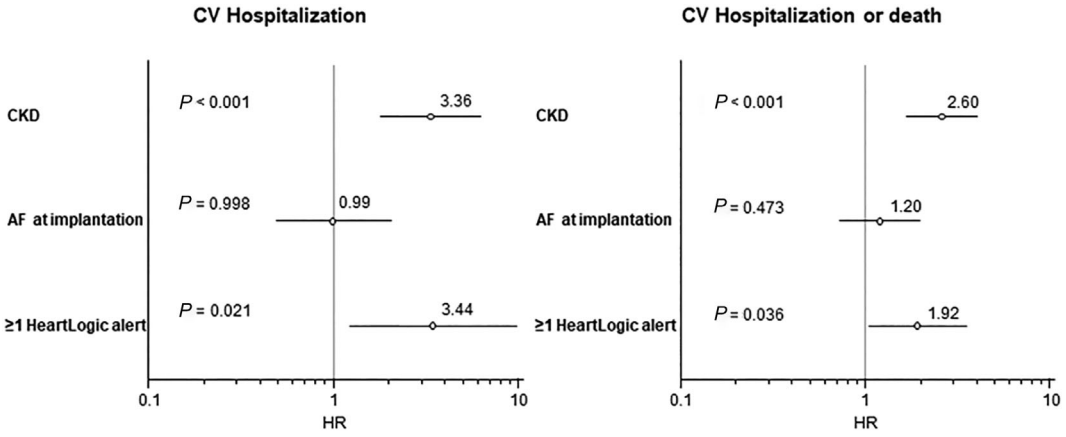
The trends in the average index and sensor values surrounding the HeartLogic alert are reported in *Figures S1–S3*. On comparing the trends during clinically stable periods (average calculated 30 days prior to the alert, i.e., −60 to −30 days) we found no differences between CRT-D and ICD patients. However, thoracic impedance was significantly lower in CKD than non-CKD patients (*Table* S2). Moreover, we found a higher third sound amplitude and nocturnal heart rate, and lower first sound amplitude in AF versus non-AF patients. These differences persisted at the time of alerts (all $P < 0.05$). In patients stratified by device type, CKD and AF, we measured significant changes in all contributing sensors (paired *t*-test; $P < 0.05$) from clinically stable periods to the time of alert.

Discussion

In the present study, we evaluated the risk stratification ability of the HeartLogic algorithm in HF patients who received either CRT-D or ICD, and we investigated the impact of common cardiovascular and non-cardiovascular co-morbidities. The burden of HeartLogic alerts was similar between CRT-D and ICD patients, while patients with AF on implantation and CKD seemed more exposed to alerts. Nonetheless, the association between clinical events and the occurrence of HeartLogic alerts during follow-up, as well as the time in the IN-alert state, was maintained after correction for these baseline confounders, and the ability of the HeartLogic algorithm to identify periods of significantly increased risk of clinical events was confirmed both in the overall population and in patients stratified by device type, CKD and AF.

HF and CKD frequently coexist, as they share common risk factors.[14,15] Chronic kidney disease may worsen cardiovascular function and is a major independent determinant of increased mortality and morbidity in HF.[16,17,18] There is also a need for tools for optimizing the therapeutic management of patients with HF and concomitant CKD. Indeed, trials have shown that, although these patients are at higher risk of events, the beneficial effects of medical therapy are similar, if not greater, than in patients with normal renal function.[19,20] Moreover, despite differences in baseline

Figure 2 Multivariate analysis. After correction for CKD and AF on implantation, the occurrence of at least one HeartLogic alert was associated with the occurrence of the combined endpoint of cardiovascular hospitalization (HR: 3.44, 95% CI: 1.22–9.76, *P* = 0.021) and cardiovascular hospitalization or death (HR: 1.92, 95% CI: 1.05–3.51, *P* = 0.036).



characteristics between patients with impaired renal function and those without, no interaction between drug effects and renal function has been noted in subgroup analyses of trials.[21,22,23,24] Similar considerations apply to patients with AF. AF is frequent in HF,[25,26] and these conditions can cause or exacerbate each other through mechanisms such as structural cardiac remodelling, activation of neurohormonal systems, and rate-related LV impairment.[27] Indeed, the development of AF in patients with chronic HF is associated with a worse prognosis, including stroke and increased mortality.[28,29] Hence, cases of AF coexisting with HF also require careful and specific therapeutic management. Indeed, although the relief of congestion may reduce sympathetic drive and ventricular rate and increase the probability of spontaneous return to sinus rhythm, the presence of AF may reduce or annul the prognostic benefits of beta-blockers and render ivabradine ineffective.[30,31]

Modern ICD diagnostic algorithms continuously measure clinical variables and have been designed to provide early warning of changes in HF status and to allow prompt intervention to prevent disease progression. Specifically, multiparameter algorithms combine data from multiple sensors which record parameters (heart rate and respiratory rate, rapid shallow breathing index, third and first heart sounds, thoracic impedance and activity) that are objective measurements of the underlying pathophysiology associated with signs and symptoms of worsening HF.[32,33,34,35,36] This system displayed high sensitivity and long warning times both in the validation study[11] and in subsequent clinical experiences.[37,38,39] The IN or OUT of alert state defined by the algorithm has also proved able to identify periods when patients are at significantly increased risk of worsening HF,[12,40] potentially allowing resources to be better targeted to this vulnerable patient population. In the present analysis, we confirmed the risk stratification ability of the HeartLogic index, as well as high values of sensitivity for detecting major clinical events and low false-positive rates, in subgroups of patients not studied in previous investigations. Indeed, non-CRT ICD patients were not included in the seminal MultiSENSE study.[11] The follow-up of these patients may differ from that of CRT patients, as they do not benefit from the well-known post-implantation improvements induced by CRT in terms of cardiac function and functional capacity. Moreover, the potentially different triggering mechanisms of worsening HF episodes, which in CRT patients are frequently linked to the loss of biventricular pacing owing to suboptimal device programming, premature ventricular complexes or uncontrolled ventricular rate during AF,[41,42] might result in a different performance of the diagnostic algorithm and its contributing sensors. Indeed, the association between biventricular pacing percent and multiple sensor changes in patients with HeartLogic-enabled CRT devices has recently been shown.[43] Similarly, a different performance of the diagnostic algorithm could not be excluded in patients with AF, because ventricular rate is one of the contributing parameters of the combined index, and the irregular heart rate could have impacted the accelerometer-based assessment of first and third heart sounds. Moreover, patients with CKD might experience changes in fluid status that affect the assessment of the thoracic impedance index component.[44] In our analysis of the average sensor values during clinically stable periods, we noted a higher nocturnal heart rate in AF patients, together with higher third sound and lower first sound amplitude, that is, possible signs of chronically reduced ventricular efficiency. Moreover, in CKD patients, we found lower baseline thoracic impedance, that is, chronic fluid overload. These differences, which also persisted at the time of alerts, demonstrated the sensitivity of the ICD sensors to the worse chronic clinical conditions of patients affected by co-morbidities, but did not impact the detection ability of

the algorithm, because all ICD sensors equally contributed to the HeartLogic alerts in all patient subgroups. The differences in sensor values might suggest the possibility of adapting the weight of each individual component of the combined index according to the patient's clinical profile, in order to improve the detection accuracy. However, given the good performance of the existing algorithm demonstrated in all subgroups, increasing the complexity of the system and requiring information to be entered manually do not seem necessary. The system allows customization of the index threshold which, as demonstrated in the MultiSENSE study,[11] allows to improve sensitivity or minimize unexplained alerts. In this study, the centres did not adjust the threshold which was set to the nominal value in all patients. However, Gardner et al. demonstrated high risk stratification performance for the entire range of configurable thresholds.[12] In conclusion, we confirmed that, in patients with HeartLogic-enabled ICD or CRT-D, the risk of clinical events is significantly increased during IN alert periods, regardless of the type of device and the presence of cardiovascular and non-cardiovascular co-morbidities. As these conditions are known to affect disease severity and prognosis, AF and CKD patients could be those who benefit most from the addition of advanced tools for remote disease management in the diagnostic and prognostic armamentarium, which currently includes clinical assessment, non-invasive and invasive testing, and natriuretic peptide assessment. Moreover, although N-terminal pro-B-type natriuretic peptide (NT-proBNP) assessment is recommended in HF for prognostication,[45] AF and CKD are among the causes that might reduce its diagnostic accuracy.[1] In patients with these conditions, the HeartLogic algorithm might be of help. Indeed, the alert status has been shown to augment the ability of baseline NT-proBNP to stratify HF risk,[12] and recently the IN alert status has proved to be associated with higher NT-proBNP values.[39] These results are reassuring from the point of view of the diagnostic accuracy of the algorithm. However, a preventive treatment strategy in response to alerts must be implemented to obtain a better outcome for monitored HF patients. Some studies have already suggested the potential value of a timely therapeutic intervention in response to alerts.[40,46] However, additional studies are required in order to test the efficacy of specific interventions.

Limitations

The main limitation of this study is its observational design. Moreover, physicians were not blinded to the HeartLogic index, and no predetermined actions were prescribed in response to alerts; this may have introduced a bias into our analysis of the risk stratification ability of the algorithm. In addition, the baseline assessment of the renal function was based on local measurements by the investigators, with no standardization of assay methods.

Conclusions

In the present study, the burden of HeartLogic alerts was similar between CRT-D and ICD patients, while patients with AF and CKD seemed more exposed to alerts. Nonetheless, the ability of the HeartLogic algorithm to identify patients during periods of significantly increased risk of clinical events was confirmed, regardless of the type of device and the presence of AF or CKD.

Conflict of interest statement

M. Campari and S. Valsecchi are employees of Boston Scientific, Inc. No other conflicts of interest exist.

Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure S1. Average HeartLogic index and sensor values surrounding the HeartLogic alert. Patients are stratified according to device type (CRT-D versus ICD).
Figure S2. Average HeartLogic index and sensor values surrounding the HeartLogic alert. Patients are stratified according to the presence of chronic kidney disease at baseline.
Figure S3. Average HeartLogic index and sensor values surrounding the HeartLogic alert. Patients are stratified according to the presence of atrial fibrillation on implantation.
Table S1. Sensitivity for detecting study endpoints and false-positive rate for all patients and all subgroups of patients.
Table S2. Matched sensor data during Baseline (−60 to −30 days) and Alert (0 to 6 days), stratified by device type, chronic kidney disease and atrial fibrillation on implantation.
Data S1. Supporting Information.

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