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ORIGINAL ARTICLE

Protocol-driven remote monitoring of cardiac resynchronization therapy as part of a heart failure disease management strategy

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ABSTRACT

Background: Cardiac resynchronisation therapy (CRT) is an established treatment for heart failure (HF) with reduced ejection fraction. CRT devices are equipped with remote monitoring functions, which are pivotal in the detection of device problems, but may also facilitate disease management. The aim of this study was to provide a comprehensive overview of the clinical interventions taken based on remote monitoring.

Methods: This is a single centre observational study of consecutive CRT patients ($n = 192$) participating in protocol-driven remote follow-up. Incoming technical- and disease-related alerts were analysed together with subsequently triggered interventions.

Results: During 34 ± 13 months of follow-up, 1372 alert-containing notifications were received (2.53 per patient-year of follow-up), comprising 1696 unique alerts (3.12 per patient-year of follow-up). In 60%, notifications resulted in a phone contact. Technical alerts constituted 8% of incoming alerts (0.23 per patient-year of follow-up). Rhythm (1.43 per patient-year of follow-up) and bioimpedance alerts (0.98 per patient-year of follow-up) were the most frequent disease-related alerts. Notifications included a rhythm alert in 39%, which triggered referral to the emergency room (4%), outpatient cardiology clinic (36%) or general practitioner (7%), or resulted in medication changes (13%). Sole bioimpedance notifications resulted in a telephone contact in 91%, which triggered outpatient evaluation in 8% versus medication changes in 10%. Clinical outcome was excellent with 97% 1-year survival.

Conclusions: Remote CRT follow-up resulted in 0.23 technical- versus 2.64 disease-related alerts annually. Rhythm and bioimpedance notifications constituted the majority of incoming notifications which triggered an actual intervention in 22% and 15% of cases, respectively.

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Heart failure; cardiac resynchronisation therapy; remote monitoring; disease management; clinical call centre

Introduction

Cardiac resynchronisation therapy (CRT) is a guideline-recommended treatment for symptomatic heart failure with reduced ejection fraction and left bundle branch block or very wide QRS complex (>150 ms) [1,2]. The use of CRT is rapidly increasing, with approximately 51,274 patients receiving a device yearly in Europe [3]. Remote follow-up of this group may offer distinct advantages to patients, healthcare workers and society as well. Remote CRT monitoring incorporates surveillance for technical device problems (i.e. battery status, lead integrity and dislodgement), device programming, early detection of rhythm disorders, and in some devices changes in thoracic impedance [4–9]. Implementation of a remote monitoring programme may substitute some of the scheduled outpatient device checks and, therefore, reduce the workload in outpatient device clinics [10–12]. Although some studies have shown a reduction in the total number and duration of heart failure hospitalisations [13] and improved survival [14], other studies [15,16] have shown conflicting results on a possible clinical benefit of remote monitoring.

In 2010, a dedicated remote follow-up programme of heart failure patients with an implantable cardiac device was started in our centre. A standardised protocol with pre-defined patient evaluation and treatment strategies, which has been proven to be critical in remote monitoring, was implemented [17]. Dedicated nurses, trained in electrophysiology, device follow-up as well as heart failure, reviewed all incoming alerts in a systematic and standardised manner with

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interventions triggered by protocol-based, guideline-recommended care and minimal involvement of physicians. All alerts and interventions taken were registered prospectively in a dedicated software programme. The current observational study presents a detailed overview and analysis of all remote monitoring alerts and subsequently triggered interventions in 192 CRT patients included in this programme. As such, the current research builds further on previous studies since these lack this level of detail [5].

Methods

Study design

This is an observational registry study of CRT patients from a single tertiary care centre (Ziekenhuis Oost-Limburg, Genk, Belgium), implanted between February 2010 and May 2013. Since February 2010, all CRT patients with a defibrillator (CRT-D) were asked to participate voluntarily in a remote follow-up programme. Over time, also CRT patients without defibrillator (CRT-P) were included, since these devices did not possess remote monitoring features from the beginning but started to do so over time. For the current analysis, only patients enrolled in remote follow-up within 6 months after device implantation were included. All participants provided written informed consent and were followed until the 1 February 2015. The study complies with the Declaration of Helsinki and the study protocol was approved by the local committee on human research.

Protocol-driven remote follow-up and alerts

All patients received a vendor-specific transmission device. The data collected from the CRT device were transmitted at night to the respective company databases, and subsequently transmitted to the multidisciplinary heart failure and device clinic's patient record. Dedicated nurses, trained in electrophysiology and heart failure, interpreted the notifications during working days; notifications received during the weekend were read on Monday. Patients participating in this programme are encouraged to contact caregivers at low threshold for any question and the dedicated nurses subsequently play a pivotal role to decide the level of care that is needed (i.e. education by heart failure nurse, general practitioner, general cardiologist, heart failure specialist, electrophysiologist, etc.). Alert transmissions are generated when predefined alarm thresholds were crossed. These thresholds could be adjusted as needed in individual patients (e.g. the alert for atrial fibrillation may be turned off in patients with known atrial fibrillation). In addition, all devices, independent from device manufacturer, were programmed to send a scheduled transmission report on a monthly basis and alert transmissions on a daily basis. For the purpose of this analysis only alert-containing notifications (i.e. scheduled notifications including an alert or unscheduled alert transmissions) were considered and alerts were classified into five categories: rhythm alerts, bioimpedance alerts, technical device alerts, missed scheduled transmissions and a miscellaneous group (Table 1). Bioimpedance is an electrical principle which

Table 1. Overview of possible alerts/intervention triggers that were monitored.

Alert category	Alert type
Rhythm alert	Sinus tachycardia
	Supraventricular tachycardia
	New-onset atrial fibrillation
	<90% biventricular pacing
	Non-sustained ventricular tachycardia
	Sustained ventricular tachycardia
	Ventricular tachycardia + ATP
	Ventricular tachycardia + DC shock
	Ventricular fibrillation + ATP
	Ventricular fibrillation + DC shock
	High ventricular rate
	Premature ventricular complexes
	Miscellaneous rhythm alert (PMT, AMS, T-wave oversensing)
Bioimpedance[a] alert	Bioimpedance threshold crossing
Technical device alert	Battery end of life
	Lead problems (lead noise, lead impedance, malcapture, malsensing)
	Device malfunction (back up mode, inappropriate AMS)
Missed scheduled transmission	Gateway problem or patient absence
Miscellaneous alerts	Heart failure management
	Changes in daily activity
	Patient contacted the clinical call centre

[a]Only for Medtronic devices, Minneapolis, MN (OptiVol and OptiVol 2.0) and St. Jude Medical devices, St. Paul, MN (CorVue).
AMS: automated mode switch; ATP: antitachycardia pacing; DC: direct current; ER: emergency room; GP: general practitioner; PMT: pacemaker-mediated tachycardia.

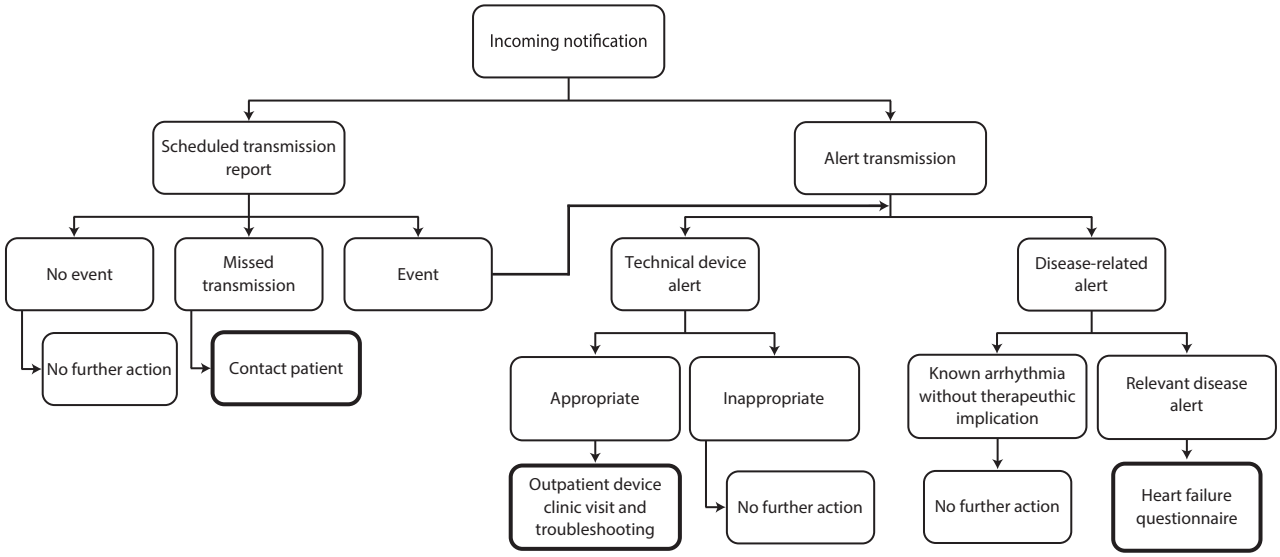

Figure 1. Schematic overview of notification handling.

represents the resistance that opposes a current to pass through the body. An inverse correlation exists between bioimpedance and the amount of body fluid. Changes in bioimpedance measurements therefore reflect changes in intrathoracic fluid status and can be used to detect emerging congestion. Bio-impedance alerts were only available for Medtronic or St. Jude devices ($n = 138$). Since combinations of alerts were possible, it was not exceptional that one notification included multiple alerts.

Intervention protocol

Incoming notifications, both scheduled transmission reports and alerts, were handled in a standardised manner with protocol-based interventions according to guideline recommendations (Figure 1) [17–19]. In case of an alert suggestive of a significant lead or device malfunction, a visit at the outpatient device clinic was arranged for troubleshooting. When a scheduled transmission report was missed, the patient was contacted by phone to identify the reason and exclude hardware malfunction. In case of a relevant disease alert, the interpreting nurse contacted the patient by phone for interrogation, using a custom-made questionnaire (Table 2). Additional questions could be asked at the discretion of the caregiver in order to gain better insight in the reason for the alert. Subsequently, appropriate feedback and general heart failure education were always provided. If any orange or red flags were discovered during the interview, further action was planned in consultation with a dedicated heart failure specialist. A notification did not result in a patient contact when it was repetitive or related to a known condition, or when a clinical follow-up visit was already scheduled for the near future.

Outpatient follow-up

Patients enrolled in remote follow-up visit the outpatient cardiology clinic for device and clinical heart failure follow-up at 6 weeks after implantation and subsequently every 6 months with a minimum of two visits per year, as per standard practice in our institution. Patients were followed until death, exclusion from remote follow-up, heart transplantation, or 1 February 2015, whichever came first.

Statistical analysis

Continuous variables are expressed as mean ± standard deviation if normally distributed, or otherwise as median (interquartile range). Normality was assessed by the Shapiro–Wilk statistic. To define statistical differences between the different CRT manufacturers, the Kruskal–Wallis test and Mann–Whitney *U* test were performed for respectively rhythm and bioimpedance-related notifications. All statistical analyses were performed using the Statistical Package for Social Sciences release 23.0 (IBM® SPSS® Inc., Chicago, IL).

Results

Study population

From 344 eligible CRT patients, 110 patients were excluded due to the presence of a CRT-P device without remote monitoring capabilities and three patients refused study participation. 33 patients were included

Table 2. Custom-made questionnaire used for patient interrogation in case of a relevant disease alert.

Last visit by the general practitioner	Date: MM/DD/YYYY Reason & findings:.....		
Daily activity	Unchanged	Worsened, but with few limitations	Significantly restricted
Dyspnea's	NYHA I or stable NYHA II	Worsening NYHA II or stable NYHA III	Worsening NYHA III or NYHA IV
Retrosternal pain	No	Stable	Unstable
Episodes of (pre-)syncope	No		Yes
Palpitations	No	Yes	
Increase in weight	No		Yes, ... kg
Edema	No	Limited and stable	Pronounced or increasing
Changes in diet	No	Yes, ...	
Changes in medication	No	Yes, ...	
	↓	↓	↓
Action	No further action	Discuss possible action with heart failure specialist	Plan action with heart failure specialist: 1. Visit general practitioner 2. Visit general cardiologist 3. Visit electrophysiologist 4. Visit heart failure specialist 5. Visit emergency room

NYHA: New York Heart Association functional class.

in the remote monitoring programme more than 6 months after device implantation and were therefore also excluded and finally six patients were excluded due to follow-up in another centre. A final study population of 192 patients was included in the study: 159 CRT-D patients (83%) and 33 CRT-P patients (17%). A study flowchart is provided in Figure 2. For 180 patients, there was a de-novo CRT implantation among which 25 patients already had a previous pacemaker or implantable cardioverter defibrillator (ICD) device and 12 patients already had a CRT device without remote monitoring enrolment and received an update or battery replacement. The median time interval between CRT implantation and start of remote follow-up was 1 day (IQR 1–2 d), with 161 (84%) patients included within one week. Patients were followed for 34 ± 13 months. The total number of elective follow-up visits to the outpatient heart failure clinic was 3.08 per patient-year of follow-up. When excluding the visits triggered by remote monitoring, this number was equal to 2.81 visits per patient-year of follow-up. Baseline characteristics of the study population at the time of implantation are provided in Table 3.

Remote follow-up notifications and alerts

A total of 1372 alert-containing remote monitoring notifications were received in 176 patients (92%) during 543 cumulative patient-years of follow-up, corresponding to 2.53 notifications per patient-year of follow-up. In 60% (820) of all notifications the patient was eventually contacted, corresponding to 1.51 telephone contacts per patient-year of follow-up, leading to 837 interventions. 165 patients (86%) were contacted at least once during follow-up. The total of 1372 alert-containing notifications comprised 1696 unique alerts (3.12 alerts per patient-year of follow-up). An overview of the frequency of each alert category is presented in Figure 3. The large majority of these alerts ($n = 1434$, 85%) were disease-related (i.e. 775 rhythm, 532 bioimpedance and 127 miscellaneous), with missed scheduled transmissions ($n = 134$) and technical device alerts ($n = 128$) each representing almost 8%.

An overview of the interventions that resulted from the alerts when the patient was contacted is shown in Figure 4. Telephonic heart failure education was

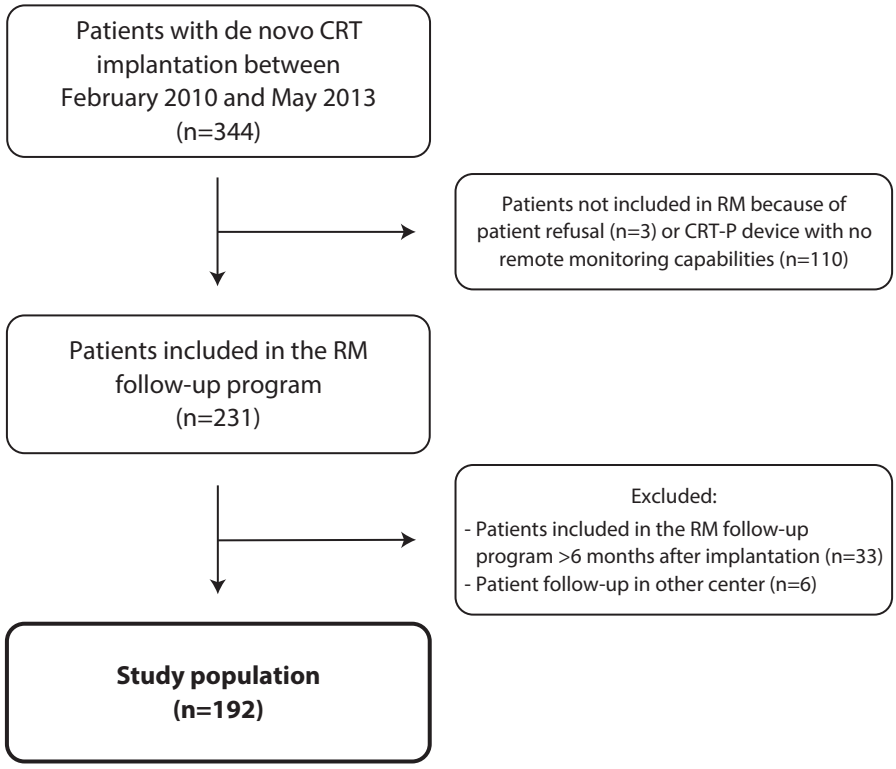

Figure 2. Flowchart of the study. CRT: cardiac resynchronisation therapy; RM: remote monitoring.

Table 3. Baseline characteristics of the study population ($n = 192$).

Variables	Study population ($n = 192$)
Age, years	71 ± 11
Male gender	153 (80%)
NYHA functional class (II/III)	24/125 (16/83%)
Left ventricular ejection fraction, %	29 ± 9
QRS width, ms	148 ± 28
Ischemic heart disease	114 (59%)
Valvular surgery	21 (11%)
Atrial fibrillation	80 (42%)
Diabetes	44 (23%)
Chronic obstructive pulmonary disease	26 (14%)
Medication use	
Renin–angiotensin system blocker	161 (84%)
Beta blocker	183 (95%)
Spironolactone	135 (70%)
Loop diuretic	92 (48%)
Digoxin	29 (15%)
Statin	114 (59%)
CRT manufacturer	
Medtronic	83 (43%)
St Jude Medical	69 (36%)
Biotronik	38 (20%)
Boston Scientific	2 (1%)

Continuous data are expressed as mean ± SD if normally distributed and dichotomous data are expressed as *n* (%). NYHA: New York Heart Association.

deemed sufficient in 530 cases (63%). The alarm resulted in a hospital admission or an emergency room visit in 1%. About 18% of cases were managed through the outpatient cardiology clinic. In 13% of cases, the patient was asked to consult the general practitioner and in 9%, the general practitioner was advised to change the patient's medication (i.e. 6% changes in (loop) diuretics and 3% changes in other medications). In the remainder of cases, technical support was provided (5%).

For the purpose of the current study, no detailed time logging was performed. However, Ziekenhuis Oost-Limburg has currently over 900 patients in active remote monitoring follow-up. The remote follow-up of these patients by the nurses takes about five to six hours a day. Therefore, it can be calculated that the time spent daily by the remote monitoring nurses to review all incoming alert-containing notifications for the 192 patients included in the current study is equal to 1.07–1.28 h.

Technical device alerts

Over the total follow-up period, 128 technical device alerts were received for lead problems ($n = 81$), loss of capture ($n = 24$), device malfunction ($n = 17$), a battery that was end of life ($n = 4$) or technical support ($n = 2$). This corresponded to 0.23 technical device alerts per patient-year of follow-up. In the four cases where a battery end of life alert was triggered, a device exchange was planned. In case of device, lead or lead threshold problems, the patient was asked to visit the hospital for further evaluation and adjust device settings when appropriate. In addition, the clinical call centre registered 134 missed scheduled transmissions,

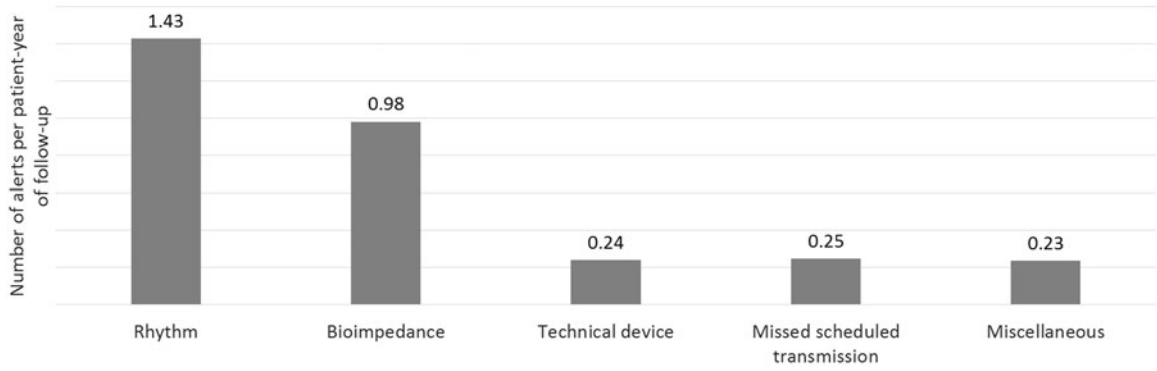

Figure 3. Frequency of alert categories with the number of alerts per patient-year of follow-up presented above.

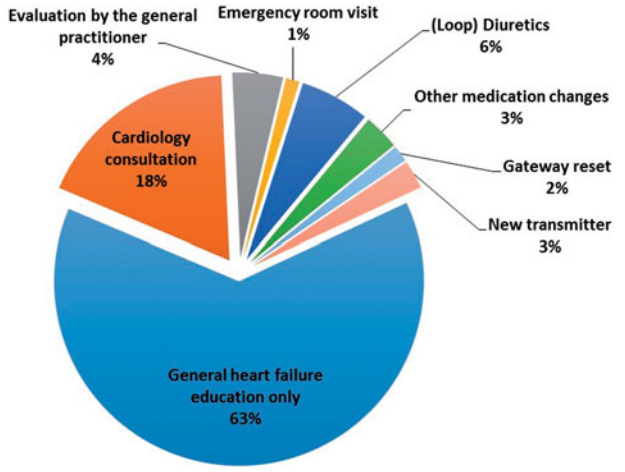

Figure 4. Overview of the interventions triggered by remote follow-up alerts when the patient was contacted.

in which case the patient was contacted and a gateway reset or new transmitter was provided if needed.

Approach to rhythm and bioimpedance alerts

Rhythm (775) and bioimpedance (532) alerts constituted the large majority of relevant disease-related alerts. The 775 rhythm alerts were comprised in 610 notifications which were received in 144 patients (75%). A detailed overview of the distribution of rhythm alarms and the specific interventions they triggered is shown in Table A1 in the Appendix. Notifications including a rhythm alert were deemed clinically relevant and thus warranting a phone call to the patient in 235/610 cases (39%) and initiated 248 interventions in total (Figure 5, left part). In 4% of cases, the patient was asked to visit the emergency room or an outpatient evaluation was arranged with the patient's cardiologist (36%) or general practitioner (7%) and medical therapy was adjusted in 13%. In 40% of cases, no further action was taken and reinforcement of heart failure education was sufficient. No differences were found for the number of rhythm-related notifications across the different CRT manufacturers.

Of all bioimpedance-containing notifications (532), 485 notifications contained only a bioimpedance alert with no combination of other alerts. These sole bioimpedance notifications triggered 439 phone calls to which 445 interventions were coupled (Figure 5, right part). In the remainder 46 cases, the patient was not contacted due to a recent outpatient visit or an outpatient visit scheduled in the near future or because of a known ongoing bioimpedance threshold crossing. Medication was changed in 10%, while an outpatient evaluation with the patient's general practitioner or cardiologist was arranged in both 4% of cases. In 82% of cases, only general heart failure education was provided and no further action was implied since patient interrogation often did not reveal any acute signs of congestion. No differences were found for the amount of bioimpedance-containing notifications across the different CRT manufacturers.

Clinical outcome

During the total follow-up 25 patients died, leading to 1-year and 3-year survival rates of 97% and 88%, respectively. After 1 year of follow-up, 176 patients (92%) were free from hospital admissions with a primary diagnosis of heart failure and 169 (88%) were free from death and heart failure readmission. At 3-year follow-up, these numbers were equal to 85% and 75% respectively. In total, there were 214 cardiac-related hospitalisations for 86 (45%) patients of which 133 were non-elective and 45 were heart failure-related. For those who had at least one cardiac-related hospitalisation, the median length of stay was 7 d (IQR 3–18).

Discussion

CRT is an established therapy in the treatment of heart failure with reduced ejection fraction and conduction

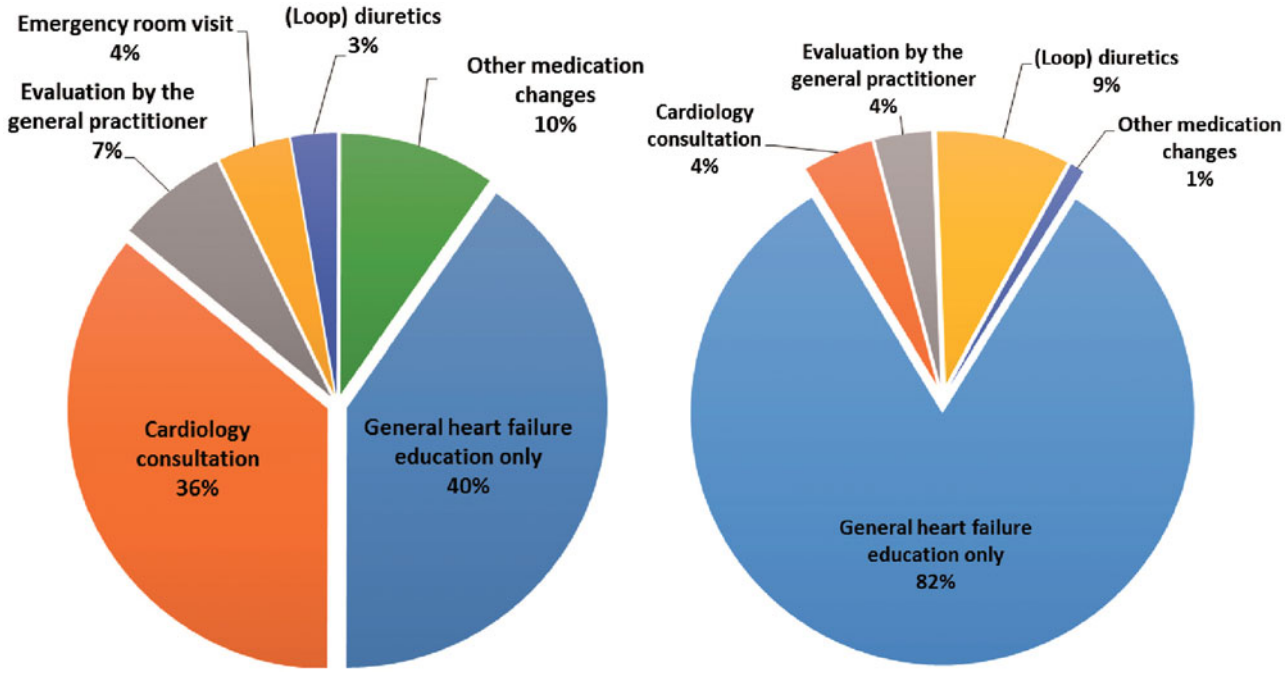

Figure 5. Overview of the interventions that resulted from relevant rhythm alerts (left) and bioimpedance alerts (right) for which the patient was contacted by phone.

delay [1,2]. In such patients, the presence of an implantable cardiac device offers the attractive possibility for remote monitoring. The current observational registry study provides a clear insight in a single centre experience of standardised protocol-driven remote follow-up of a large cohort of patients with heart failure treated with CRT, who were followed in a dedicated heart failure clinic. It offers a comprehensive and detailed overview of incoming alarm notifications and individual alerts. The single Belgian tertiary care centre where the study was performed accounts for approximately 15% of Belgian CRT implantations [20].

Major insights were (1) in case of a remote monitoring notification, the patient was contacted for further evaluation in 60% of cases; (2) technical device alerts and missed transmissions were relatively infrequent, each constituting only 8% of the total number of incoming alerts; (3) rhythm (46%) and bioimpedance (31%) alerts constituted the majority of incoming disease-related alerts; (4) notifications including a rhythm alert triggered an actual intervention in 22%, while this was only 15% for sole bioimpedance notifications.

A shortcoming in current studies is the lack of information as to what clinical actions were taken based on the information gathered via remote monitoring, making it difficult to assess which components of a programme are implied in perceived outcome benefits [5]. A better insight and standardisation in remote monitoring strategies is therefore urgently needed. The current study provides helpful information in this respect as it provides a detailed description of a standardised remote monitoring protocol and reports both the frequency and therapeutic consequences of remote monitoring alerts in depth with a mean follow-up of almost three years.

A first observation is that alerts were frequent, with an incidence of approximately three per patient-year of follow-up. In the majority of cases (60%), these alerts resulted in the patient being contacted for further evaluation and/or therapeutic intervention. In addition, progress has been made in recent years to reduce transmission problems as these alerts represented only 8% of all incoming alerts. Furthermore, technical alarms for lead and device problems were also relatively infrequent (8%) and will probably decrease over time with further technical innovations. In contrast, rhythm alerts were the most frequent and triggered further therapeutic interventions in 22% of cases. Bioimpedance alerts triggered frequent phone contacts (91%), but led to few therapeutic interventions (15%), indicating a low specificity of these alerts. This may suggest that when financial or logistic constraints apply to a remote follow-up programme for CRT, prioritising focus on rhythm alerts could be an efficient strategy. In this study, cardiology consultation was the most frequently triggered intervention (18%), but many patients were also helped through instructions by phone (63%) or via their general practitioner

(13%). Only a very small proportion of alerts (<5%) resulted in hospital admission. Remote monitoring as organised in the current study did not lead to more frequent visits to the emergency room for trouble-shooting, as has been observed in some studies [21]. Overall admission rate in this study at one year of follow-up was 12%. Our results emphasise that remote follow-up of CRT patients is feasible with direct feedback loops that require minimal input from physicians, but rely on specialised caregivers trained in electrophysiology and heart failure with patients having a low threshold to contact caregivers for any question and the dedicated nurses subsequently play a pivotal role to decide the level of care that is needed. With such an approach, clinical outcome was comparable with the literature with one and three-year survival rates of, respectively, 97% and 88% and, respectively, 92% and 85% were free from hospital admissions with a primary diagnosis of heart failure [14].

This study should be interpreted in the light of some limitations. First, it was a relatively small and single-centre study, which may impact its external validity. Secondly, while clinical outcomes may be compared with other contemporary CRT cohorts, study inclusion was based on voluntary participation to remote follow-up and there was no control group. Therefore, one cannot exclude the possibility that enrolled patients were more motivated for follow-up with better expected compliance to therapies. However, at our centre, the overwhelming majority (>99%) of patients agrees with remote follow-up, reducing the risk for selection bias. Finally, remote monitoring options for CRT-P devices were limited at the start of the study, leading to less such patients included.

Conclusions

Remote follow-up of CRT patients resulted in 3.12 alerts per patient-year of follow-up: 0.23 technical device alerts versus 2.64 disease-related alerts per patient-year of follow-up. Rhythm and bioimpedance alerts constituted the majority of incoming alerts (respectively, 1.43 versus 0.98 alerts per patient year of follow-up) and triggered an intervention in 22% and 15%, respectively. A transition from device to disease monitoring has been observed in recent years. By structured notification handling according to standardised questionnaires and decision trees in a well-organised remote monitoring follow-up programme, survival rates reach comparable results as those from randomised controlled trials. In the future, this disease management will only improve by enhanced device algorithms and multi-parameter handling.

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Disclosure statement

The authors have no conflicts of interests to declare.

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References

[1] McMurray JJ, Adamopoulos S, Anker SD, et al. ESC guidelines for the diagnosis and treatment of acute and chronic heart failure 2012: the Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2012 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association (HFA) of the ESC. Eur J Heart Fail. 2012;14:803–869.

[2] Yancy CW, Jessup M, Bozkurt B, et al. 2013 ACCF/AHA Guideline for the Management of Heart Failure: A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol. 2013;62:e147–239.

[3] Raatikainen MJ, Arnar DO, Zeppenfeld K, et al. Statistics on the use of cardiac electronic devices and electrophysiological procedures in the European Society of Cardiology countries: 2014 report from the European Heart Rhythm Association. Europace. 2015;17 Suppl 1:i1–i75.

[4] Mullens W, Grimm RA, Verga T, et al. Insights from a cardiac resynchronization optimization clinic as part of a heart failure disease management program. J Am Coll Cardiol. 2009;53:765–773.

[5] Linde C, Braunschweig F. Cardiac resynchronization therapy follow-up: role of remote monitoring card. Electrophysiol Clin. 2015;7:797–807.

[6] Varma N, Piccini JP, Snell J, et al. The relationship between level of adherence to automatic wireless remote monitoring and survival in pacemaker and defibrillator patients. J Am Coll Cardiol. 2015;65: 2601–2610.

[7] Lazarus A. Remote, wireless, ambulatory monitoring of implantable pacemakers, cardioverter defibrillators, and cardiac resynchronization therapy systems: analysis of a worldwide database. Pacing Clin Electro. 2007;30 Suppl 1:S2–S12.

[8] Saxon LA, Hayes DL, Gilliam FR, et al. Long-term outcome after ICD and CRT implantation and influence of remote device follow-up: the ALTITUDE survival study. Circulation. 2010;122:2359–2367.

[9] Crossley GH, Boyle A, Vitense H, et al. The CONNECT (Clinical Evaluation of Remote Notification to Reduce Time to Clinical Decision) trial: the value of wireless remote monitoring with automatic clinician alerts. J Am Coll Cardiol. 2011;57:1181–1189.

[10] Landolina M, Perego GB, Lunati M, et al. Remote monitoring reduces healthcare use and improves quality of care in heart failure patients with implantable defibrillators: the evolution of management strategies of heart failure patients with implantable defibrillators (EVOLVO) study. Circulation. 2012;125:2985–2992.

[11] Ladapo JA, Turakhia MP, Ryan MP, et al. Health care utilization and expenditures associated with remote monitoring in patients with implantable cardiac devices. Am J Cardiol. 2016;117:1455–1462.

[12] Klersy C, Boriani G, De Silvestri A, et al. Effect of telemonitoring of cardiac implantable electronic devices on healthcare utilization: a meta-analysis of randomized controlled trials in patients with heart failure. Eur J Heart Fail. 2016;18:195–204.

[13] Louis AA, Turner T, Gretton M, et al. A systematic review of telemonitoring for the management of heart failure. Eur J Heart Fail. 2003;5:583–590.

[14] Hindricks G, Taborsky M, Glikson M, et al. Implant-based multiparameter telemonitoring of patients with heart failure (IN-TIME): a randomised controlled trial. Lancet. 2014;384:583–590. PubMed PMID: 25131977; eng.

[15] Boriani G, Da Costa A, Quesada A, et al. Effects of remote monitoring on clinical outcomes and use of healthcare resources in heart failure patients with biventricular defibrillators: results of the MORE-CARE multicentre randomized controlled trial. Eur J Heart Fail. 2016;19:416–425.

[16] Cowie MR, editor. REM-HF – Remote monitoring: an evaluation of implantable devices for management of heart failure patients. European Society of Cardiology 2016 Congress; 2016 August 28; Rome, Italy.

[17] Hindricks G, Varma N. Remote monitoring and heart failure: monitoring parameters, technology, and workflow. Eur Heart J. 2016;37:3164–3166.

[18] Wilkoff BL, Auricchio A, Brugada J, et al. HRS/EHRA Expert Consensus on the Monitoring of Cardiovascular Implantable Electronic Devices (CIEDs): description of techniques, indications, personnel, frequency and ethical considerations: developed in partnership with the Heart Rhythm Society (HRS) and the European Heart Rhythm Association (EHRA); and in collaboration with the American College of Cardiology (ACC), the American Heart Association (AHA), the European Society of Cardiology (ESC), the Heart Failure Association of ESC (HFA), and the Heart Failure Society of America (HFSA). Endorsed by the Heart Rhythm Society, the European Heart Rhythm Association (a registered branch of the ESC), the American College of Cardiology, the American Heart Association. Europace. 2008;10:707–725.

[19] Slotwiner D, Varma N, Akar JG, et al. HRS Expert Consensus Statement on remote interrogation and monitoring for cardiovascular implantable electronic devices. Heart Rhythm: Off J Heart Rhythm Soc. 2015;12:e69–e100.

[20] Verbrugge FH, De Vusser P, Rivero-Ayerza M, et al. Cardiac resynchronization therapy with or without defibrillator: experience from a high-volume Belgian implantation centre. Acta Cardiol. 2013;68:37–45.

[21] van Veldhuisen DJ, Braunschweig F, Conraads V, et al. Intrathoracic impedance monitoring, audible patient alerts, and outcome in patients with heart failure. Circulation. 2011;124:1719–1726.

Appendix

Table A1. Detailed overview of the rhythm and sole bioimpedance alerts and the triggered interventions.

			Triggered intervention				
Type of alert	Number of alerts (%)	Further action by investigational site (%)	Diuretic adjustment (%)	Other medication adjustment (%)	General practitioner consultation (%)	Cardiology consultation (%)	Emergency room referral (%)
Rhythm-related alerts							
VF	9 (1)	6 (67)	0	0	0	4 (67)	2 (33)
VT with shock	5 (1)	2 (40)	0	0	0	2 (100)	0
VT with ATP	38 (5)	14 (37)	0	3 (21)	0	8 (57)	3 (21)
VT without intervention	73 (9)	19 (26)	0	3 (16)	5 (26)	9 (47)	3 (16)
AF	138 (18)	47 (34)	2 (4)	6 (13)	6 (13)	34 (72)	4 (9)
SVT not otherwise specified	100 (13)	27 (27)	2 (7)	6 (22)	8 (30)	17 (63)	0
Non-sustained VT	143 (18)	13 (9)	1 (8)	4 (31)	2 (15)	7 (54)	0
PVC	104 (13)	18 (17)	2 (11)	2 (11)	0	15 (83)	0
<90% BIV pacing	136 (18)	39 (29)	4 (10)	6 (15)	2 (5)	30 (77)	3 (8)
Decreased HR variability	18 (2)	2 (11)	0	0	0	2 (100)	0
Other	11 (1)	2 (18)	0	0	0	2 (100)	0
Sole bioimpedance alerts	485	73 (15)	38 (52)	4 (5)	16 (22)	20 (27)	0

Data are expressed as *n* (%).
VF: ventricular fibrillation; VT: ventricular tachycardia; ATP: antitachycardia pacing; AF: atrial fibrillation; SVT: supraventricular tachycardia; PVC: premature ventricular complexes; BIV: biventricular; HR: heart rate.