

Trends beyond the new normal: from remote monitoring to digital connectivity

Leonardo Calò^{1*}, Ermenegildo de Ruvo¹, Anna Maria Martino¹, Günther Prenner², Martin Manninger², and Daniel Scherr²

¹Division of Cardiology, Policlinico Casilino, Via Casilina 1049, 00169 Rome, Italy; and

²Clinical Department of Cardiology, University of Graz, Graz, Austria

KEYWORDS

Telemedicine;
COVID-19;
Remote monitoring;
Digital medicine

COVID pandemic emergency has forced changes from traditional in-person visits to application of telemedicine in order to overcome the barriers and to deliver care. COVID-19 has accelerated adoption of digital health. During this time, the distance is itself a prevention tool and the use of technology to deliver healthcare services and information has driven the discovery of mobile and connected health services. Health services should be prepared to integrate the old model of remote monitoring of CIEDs and adopt new digital tools such as mobile Apps and connected sensors.

The COVID-19 has catalysed digital medicine

The pandemic public health emergency has forced changes from traditional to 'new' forms of health care access and delivery across all countries. During lockdown, in-person visits have become the last option for meeting patients. Telemedicine (the use of technologies to remotely diagnose, monitor, and treat patients) and digital health (the application of technologies to help patient management of illnesses) have been applied and combined to overcome the barriers and to deliver care. Thus, COVID-19 has accelerated adoption of telemedicine tools even in 'digital miscreant'. These features rapidly evolved from 'gadgets' to useful tools, especially when overall health care system capacity was stretched to its maximum, as in COVID-19 pandemic. The term telemedicine (from the Latin 'medicus' and Greek 'tele') literally means 'healing at a distance'. During this time, the distance is itself a treatment and a prevention tool, and the use of technology to deliver healthcare services and information at a distance has driven the discovery of mobile and connected health services.¹⁻⁵ For example, providing remote radiology consultations to confirm COVID-19 suspicion after a computed tomography (CT) scan. Restricted

clinic access deeply influenced the management of non-COVID patients. Heart rhythm professionals are fortunate to have a choice of wireless technologies to relay monitored information to maintain connection. Cardiac implantable devices allow convenient monitoring for arrhythmias on a long-term basis due to the comfort associated with their small size and ease of use while reducing patient and health care worker exposure. Remote cardiac implantable electronic device (CIED) monitoring has existed for decades. It has been strongly endorsed by professional societies, but in practice, only a fraction of its diagnostic and therapeutic capabilities has been utilized until now.^{6,7} Available remote patient monitoring technologies like HeartLogic, CardioMEMS, and Vree Health to name a few, should be adopted quickly to provide a better assessment of heart failure (HF) clinical status while maintaining social distancing through the performance of virtual visits. Such invasive and non-invasive technologies may better allow clinicians to keep patients with HF safely in their homes and minimize the need for in-person hospital or clinic visits. Despite its effectiveness, remote monitoring is significantly underused because of a variety of patient-based and system-based issues. Remote monitoring should be used in most circumstances to reduce the need for non-current clinic visits. During this pandemic, remote monitoring should be reconsidered in all patients who have been not yet enrolled.

*Corresponding author. Tel: +39 06 23188406, Fax +39 06 23188410, Email: leonardocalo.doc@gmail.com

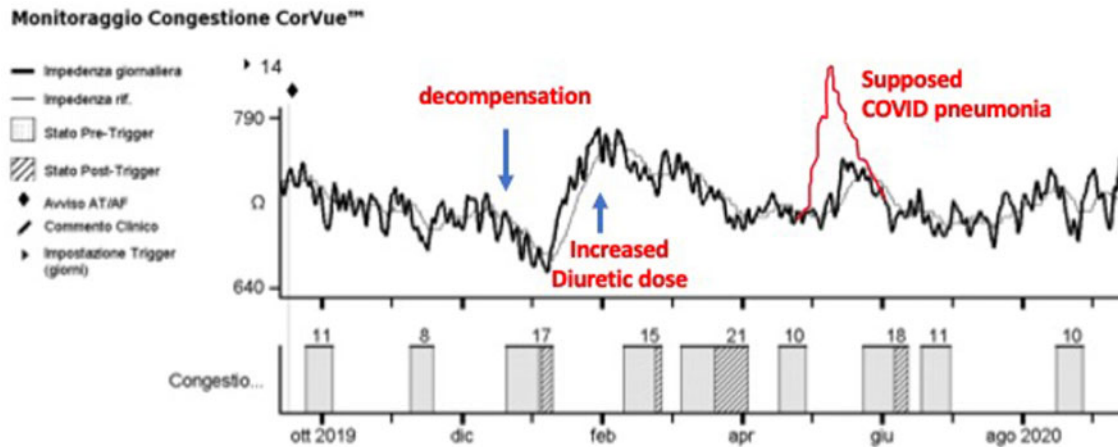


Figure 1: In this case, we found in the past a decrease in thoracic impedance following a high rate AF episode with reduction of biventricular stimulation. Following a telephone interview with evidence of increased body weight and dyspnoea, the of diuretic dosage was increased; after few days there was significant improvement. In the right part, a step increase is designed mimicking a COVID-19 pneumonia.

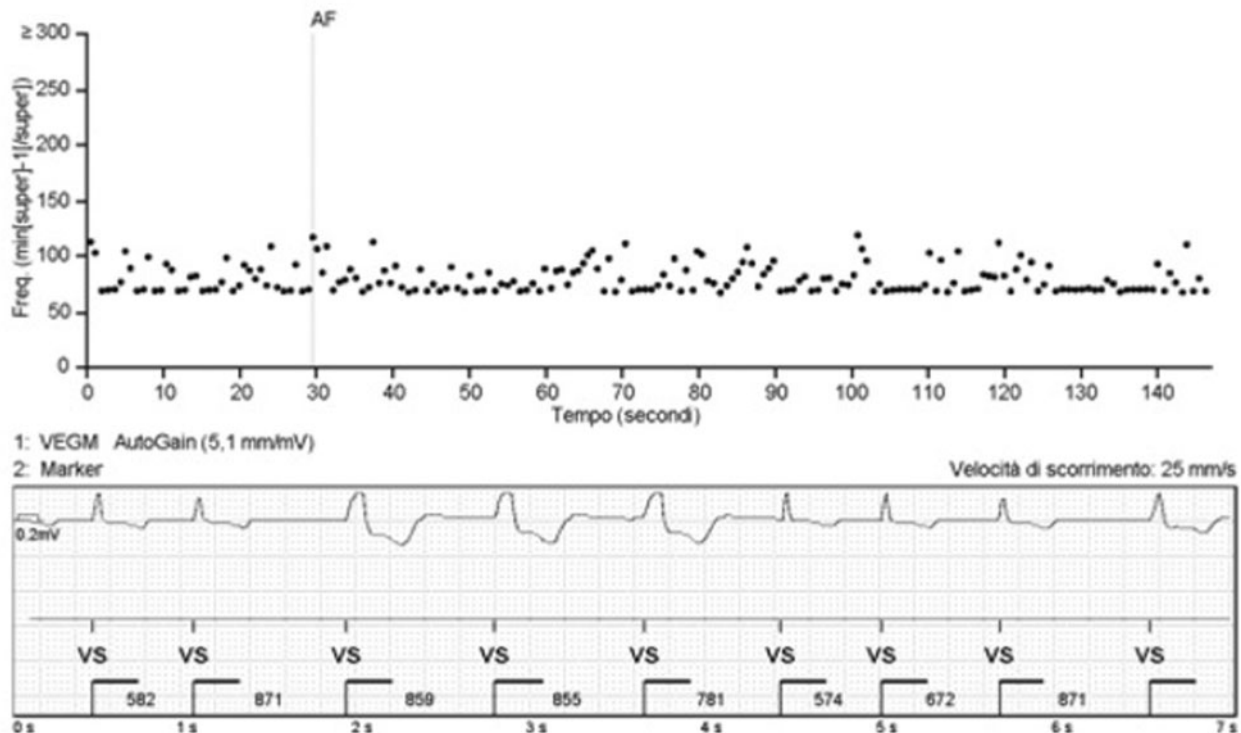


Figure 2: During an AF episode a patient already implanted with an ICM (Confirm RX), transmits both ECG and symptoms to the referral Hospital.

The new normal may benefit from digital tools and improved patient connectivity beyond traditional remote monitoring

In the past, intrathoracic impedance (ITI) drop detected by implantable devices has been used to detect the presence of pulmonary congestion. ITI is calculated by measuring the energy needed to send a small current from the battery of

a device (the ‘extrathoracic component’) to an intracardiac lead (the ‘intrathoracic component’). It was hypothesized to predict new episodes of HF decompensation. CorVue ITI monitoring algorithm was developed by St Jude Medical for its implantable cardioverter-defibrillator and cardiac resynchronization therapy with defibrillator devices. It has been hypothesized that using multiple intrathoracic vectors, the diagnostic reliability of ITI would

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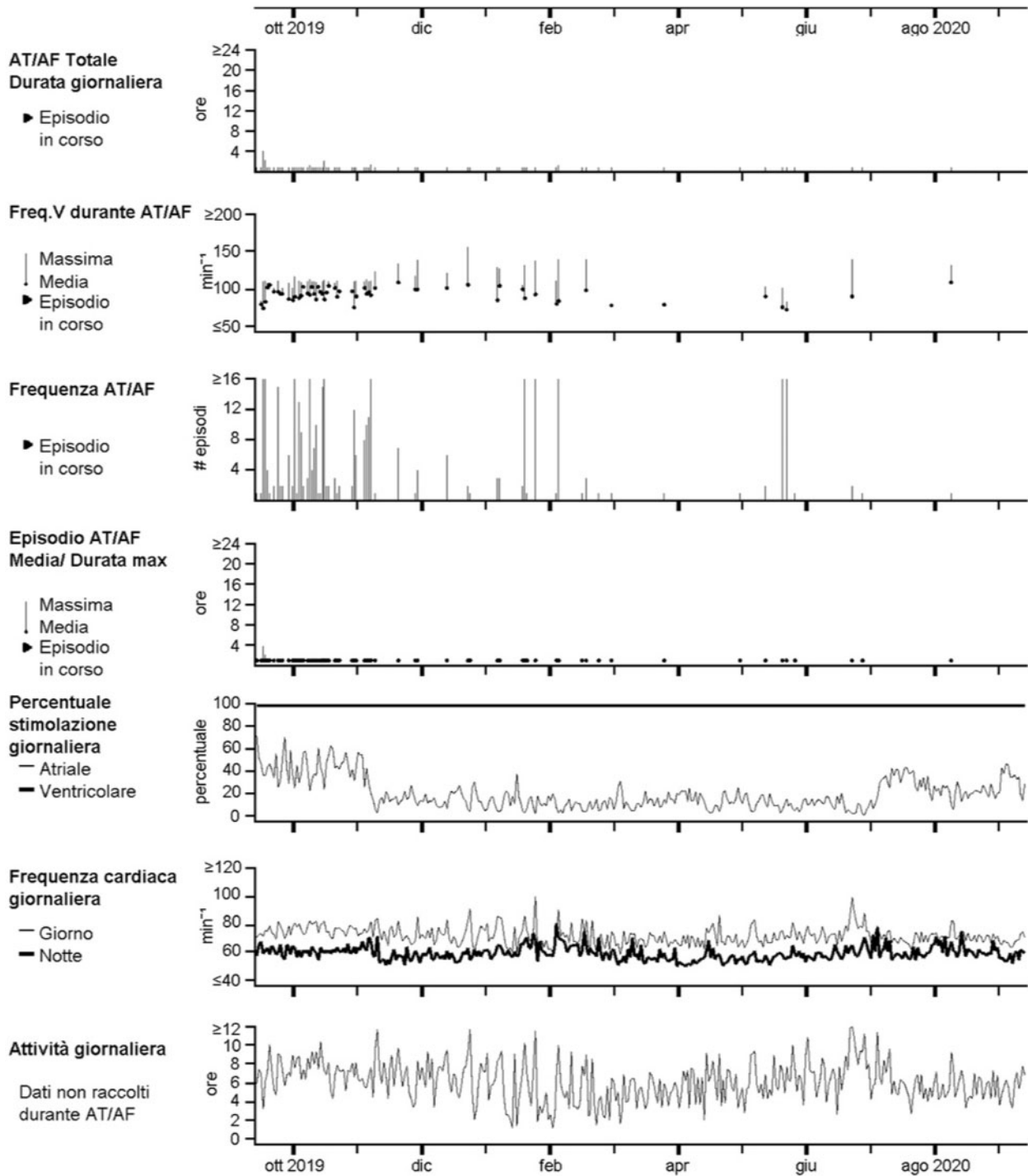


Figure 3: A representation of the remote monitoring diagnostic tools direct trend: AT/AF burden and heart rate during atrial fibrillation/atrial tachycardia (AT/AF) are showed together with rest and mean heart rate, biventricular pacing percentage, and patient's activity.

increase. But, the diagnostic efficacy of ITI measurement as an isolated data in the early detection of HF decompensation is poor, both for Optivol and CorVue algorithms. On the other hand, there are no perspective data if a sudden and steep increase of ITI with atypical features may induce the suspicion for an alternative diagnosis such as early detection of a severe COVID-19 pneumonia.⁸ Statistics like percent activity per day, resting heart rate, and mean rate per day are currently available in the CIEDs, and there is a well-known relationship between fever and heart rate.⁹

An increased thoracic impedance claims an alternative diagnosis. Normally, a lower impedance would be expected for severe HF decompensation because of fluid overload.

If lung alveoli are progressively filled up with water (pulmonary oedema due to decompensation), resistance decreases as the conductivity for electric current is higher for water than for air. Therefore, an increased thoracic impedance is very atypical for cardiac decompensation. The increase in thoracic impedance in COVID pneumonia might be explained by air trapping due to hyperinflation. Such as for HF monitoring, a multiparametric approach can confirm the suspicion and reduce mortality among at-risk patients and protect caregivers (*Figure 1*). Additionally, some implantable cardiac monitors (ICMs) contain an internal, integrated solid-state temperature sensor.¹⁰ A temperature sensor could be evaluated for possible use as a screening tool for patients with all CIEDs and move these devices towards vital sign monitors with a significant clinical impact. With a broader implementation of RM, the new normal may benefit from digital tools and improved patient connectivity beyond traditional remote monitoring. The use of wearables such as watches, smartphones is a novel approach. The need for contactless monitoring has triggered the novel implementation of digital health monitoring applications (e.g. Instant Heart Rate, PulsePoint Respond, Blood Pressure Monitor, Cardio, Blood Pressure Companion, Kardia, Qardio, FibriCheck, Cardiac Diagnosis, Blood Pressure Tracker). This type of wireless monitoring may be continued after discharge, permitting prolonged surveillance of rhythm and vital signs. Even a standard 12-lead ECG may be difficult to obtain, given the enormous burden of increasing number of COVID-19 patients. The use of modern handheld ECG (h-ECG) devices should be considered in order to reduce traditional ECG recording as much as possible to preserve resources and limit virus spread. In a recent study, the QTc in lead-I and lead-II derived from a standard 12-lead ECG was compared with a rhythm strip from a h-ECG device in healthy volunteers and hospitalized patients treated with antiarrhythmic drugs. h-ECG had a high specificity for detecting a QTc > 450ms and should thus be considered as an effective outpatient tool for monitoring patients with prolonged QTc. It can thus be used in COVID-19 patients treated with QT-prolonging drugs such as anti-viral drugs, chloroquine or hydroxychloroquine.¹¹⁻¹⁴

But new technologies may transmit multiple parameters (heart rate, sleep, oxygen desaturation index, and blood pressure) via a smartphone link to centralized hubs. New algorithms based on predictive analytics of electronic medical records (i.e. artificial intelligence) are needed to prevent re-hospitalization (predictive medicine).

The critical points for the success of telemedicine are patient compliance and frequency of transmissions. Automatic daily remote transmissions were independently associated with an increased probability of early adverse event detection. Remote monitoring (RM) efficiency and efficacy may be improved by increasing the frequency of transmission.¹⁵ Home monitoring of weight, blood pressure, heart rate, and pulse oximetry should be acquired automatically, by connected sensors, without the need for any action by the patients.

Digital medicine represents a possible solution to 'reduce' distances during this pandemic. Through a mobile application, the patients can refer symptoms, while a central telemedicine unit staffed with one or more cardiologists, technicians, and nurses can check ECG tracings and provide proactive care by avoiding hospitalization, reducing the hospital stay through a fast track (a less critical patient can be treated in less time or by remote reprogramming of CIEDs). The goal of a 'new' telemedicine model should be to integrate 'conventional' telemedicine, not replace the 'old' model. The central point is to adopt a standardized model for management of alerts and daily check of symptoms, parameters, and transmissions. In case of an alert the hospital team can remotely triage the patient (*Figure 2*) and check for new symptoms: increasing shortness of breath or fatigue, worsening peripheral oedema, or weight gain suggestive fluid overload and not attributable to alternative causes (i.e. lower respiratory infection). In cases deemed to have positive signs or symptoms of decompensation, in line with routine clinical practice suggested actions may include remote adjustment of medications, access to the primary care physician, or the outpatient HF clinic for a virtual or in-person visit. Integrating general practitioners in the remote monitoring network can further reduce delay in patient treatment and avoid hospitalization for patients at low risk (*Figure 3*).¹⁶

Conclusion

In conclusion, telemedicine tools can allow providers to provide care even in a difficult scenario like the COVID pandemic. Health care teams must continue to be prepared and preserve adequate resources for dealing with a second wave. More monitoring and diagnostic testing aspects of both inpatient and outpatient care will be served by new digital medicine. When feasible, the application of mobile apps and connected sensors should integrate the old model of remote monitoring of CIEDs.

Funding

This paper was published as part of a supplement supported by an educational grant from Abbott.

Conflict of interest: none declared.

References

1. Lakkireddy DR, Chung MK, Gopinathannair R, Patton KK, Gluckman TJ, Turagam M, Cheung JW, Patel P, Sotomonte J, Lampert R, Han JK, Rajagopalan B, Eckhardt L, Joglar J, Sandau KE, Olshansky B,

- Wan E, Noseworthy PA, Leal M, Kaufman E, Gutierrez A, Marine JE, Wang PJ, Russo AM. Guidance for cardiac electrophysiology during the COVID-19 pandemic from the Heart Rhythm Society COVID-19 Task Force; Electrophysiology Section of the American College of Cardiology; and the Electrocardiography and Arrhythmias Committee of the Council on Clinical Cardiology American Heart Association. *Heart Rhythm* 2020;17:e233-e241.
2. Lakkireddy DR, Chung MK, Deering TF, Gopinathannair R, Albert CM, Epstein LM, Harding CV, Hurwitz JL, Jeffery CC, Krahn AD, Kusumoto FM, Lampert R, Mansour M, Natale A, Patton KK, Seiler A, Shah MJ, Wang PJ, Russo AM. Guidance for rebooting electrophysiology through the COVID-19 pandemic from the Heart Rhythm Society and the American Heart Association Electrocardiography and Arrhythmias Committee of the Council on Clinical Cardiology. *Circ Arrhythm Electrophysiol* 2020;13:e008999.
 3. Abraham WT, Fiuzat M, Psołka MA, O'Connor CM. Heart failure collaborative statement on remote monitoring and social distancing in the landscape of COVID-19. *JACC Heart Fail* 2020;8:692-694. Aug;
 4. De Simone V, Guarise P, Guardalben S, Padovani N, Tondelli S, Sandrini D, Visentin E, Zanotto G. Telecardiology during the Covid-19 pandemic: past mistakes and future hopes. *Am J Cardiovasc Dis* 2020;10:34-47.
 5. Russo V, Nigro G, D'Onofrio A. COVID-19 and cardiac implantable electronic device remote monitoring: crocodile tears or new opportunity? *Expert Rev Med Devices* 2020;17:471-472.
 6. Varma N, Marrouche NF, Aguinaga L, Albert CM, Arbelo E, Choi JI, Chung MK, Conte G, Dagher L, Epstein LM, Ghanbari H, Han JK, Heidebuchel H, Huang H, Lakkireddy DR, Ngarmukos T, Russo AM, Saad EB, Saenz Morales LC, Sandau KE, Sridhar ARM, Stecker EC, Varosy PD. HRS/EHRA/APHRS/LAHRs/ACC/AHA worldwide practice update for telehealth and arrhythmia monitoring during and after a pandemic. *J Am Coll Cardiol* 2020;35623-35620.
 7. Slotwiner D, Varma N, Akar JG, Annas G, Beardsall M, Fogel RI, Galizio NO, Glotzer TV, Leahy RA, Love CJ, McLean RC, Mittal S, Morichelli L, Patton KK, Raitt MH, Pietro Ricci R, Rickard J, Schoenfeld MH, Serwer GA, Shea J, Varosy P, Verma A, Yu C-M. HRS Expert Consensus Statement on remote interrogation and monitoring for cardiovascular implantable electronic devices. *Heart Rhythm* 2015;12:e69-e100.
 8. Heggermont W, Nguyen PAH, Lau CW, Tournoy K. A steep increase in the HeartLogic index predicts COVID-19 disease in an advanced heart failure patient. *Case Rep Cardiol* 2020;2020:1-6.
 9. Jensen MM, Brabrand M. The relationship between body temperature, heart rate and respiratory rate in acute patients at admission to a medical care unit. *Scand J Trauma Resusc Emerg Med* 2015;23:A12.
 10. Whittington RH, Muessig D, Reddy R, Mohammad A, Mitchell K, Brumbaugh J, Mehta D, Hayes D. Temperature monitoring with an implantable loop recorder in a patient with presumed COVID-19. *HeartRhythm Case Rep* 2020;6:477-481.
 11. Garabelli P, Stavarakis S, Albert M, Koomson E, Parwani P, Chohan J, Smith L, Albert D, Xie R, Xie Q, Reynolds D, Po S. Comparison of QT interval readings in normal sinus rhythm between a smartphone heart monitor and a 12-lead ECG for healthy volunteers and inpatients receiving sotalol or dofetilide. *J Cardiovasc Electrophysiol* 2016;27:827-832.
 12. Chinello P, Petrosillo N, Pittalis S, Biava G, Ippolito G, Nicastri E, on behalf of the INMI Ebola Team. QTc interval prolongation during favipiravir therapy in an Ebolavirus-infected patient. *PLoS Negl Trop Dis* 2017;11:e0006034.
 13. Chung EH, Guise KD. QTC intervals can be assessed with the AliveCor heart monitor in patients on dofetilide for atrial fibrillation. *J Electrocardiol* 2015;48:8-9.
 14. Strik M, Caillol T, Ramirez FD, Abu-Alrub S, Marchand H, Welte N, Ritter P, Haïssaguerre M, Ploux S, Bordachar P. Validating QT-interval measurement using the apple watch ECG to enable remote monitoring during the COVID-19 pandemic. *Circulation* 2020;142:416-418.
 15. de Ruvo E, Sciarra L, Martino AM, Rebecchi M, Iulianella RV, Sebastiani F, Fagagnini A, Borrelli A, Scarà A, Grieco D, Tota C, Stirpe F, Calò L. A prospective comparison of remote monitoring systems in implantable cardiac defibrillators: potential effects of frequency of transmissions. *J Interv Card Electrophysiol* 2016;45:81-90.
 16. Ahmed FZ, Taylor JK, Green C, Moore L, Goode A, Black P, Howard L, Fullwood C, Zaidi A, Seed A, Cunnington C, Motwani M. Triage-HF Plus: a novel device-based remote monitoring pathway to identify worsening heart failure. *ESC Heart Fail* 2020;7:107-116.