Android based warning system for the early detection of allergic reactions

E. Diaz, R. Gutierrez, J. J. Garcia, W. Marnane*, A. Jimenez, D. Gualda

Abstract— **This work proposes an Android-based platform to warn the medical staff of the onset of allergy reactions during a provocation test in a hospital. The portable system carries out the analysis of the heart rate variability for the early detection of allergic reactions in patients undergoing allergy provocation tests at hospitals. The proposal is composed of an ECG (electrocardiogram) acquisition system and an Android device (Smartphone, Tablet) that monitors and evaluates the results in real time, increasing the safety of allergic tests. At present, food and drug allergic tests are a major problem for patients because of their long duration and intrusion. However, the authors have designed an algorithm for detecting allergy reactions that have focused on reducing the time of the tests and the number of doses. This algorithm runs on an Android platform, and it is able to provide alarms for the medical staff if there is an allergy reaction. The proposed monitoring system is very suitable for the health monitoring during the provocation tests.**

I. Introduction

The quick development and great acceptance of the concept of Internet of Things (IoT) has allowed an increase of applications dedicated to obtain clinical parameters related to the patients. Many of these applications have taken an advantage of the availability of portable devices such as Smartphones [1]. Heart Rate (HR) monitors are the most common used devices for health monitoring in Smartphones.

Due to the relationship between the heart rate with other physiological systems behavior (central nervous system, respiratory, vasomotor, thermoregulatory, etc. [2][3]), it is possible to analyze those systems by observing the HR's variability. Usually these changes are analyzed beat-by-beat, i.e. by computing the HR, which is equivalent to the time interval between each pair of adjacent heartbeats (RR intervals, Fig. 1). The obtained signal is the so-called Heart Rate Variability (HRV) signal. Fig. 2 depicts an example of HRV signal of a healthy subject performing different activities, as can be distinguished by observing the mean value of the HRV (~80 beats per minute –bpm- while sitting and ~110 while walking).

There are a lot of features of the HRV signal that have been analyzed over the last years [4]. Based on these studies it has been obtained models of the HRV signal to generate information related to different physiological systems [5]. Consequently, there are a lot of proposals to use the HRV signal as a tool for the diagnosis of diseases. With these proposals, we have designed a system for the early detection of allergic reactions based on the analysis of the HRV. Fig. 3 shows the complete system composed of an acquisition system

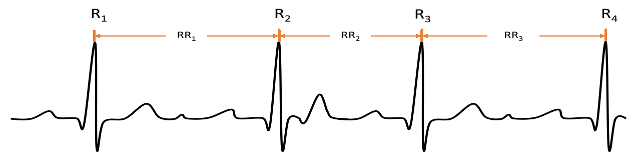

Fig. 1. Representation of RR intervals of the ECG signal.

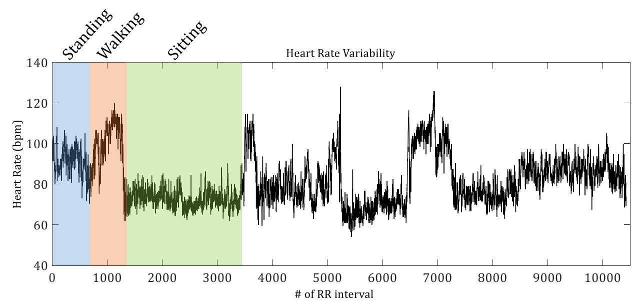

Fig. 2. Heart Rate Variability for each RR interval of a healthy subject performing different physical activities: walking, standing, sitting, etc.

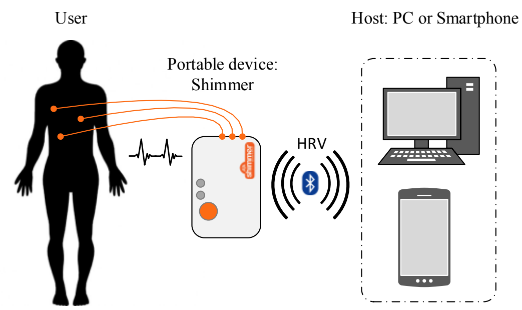

Fig. 3. Early detection system for allergic reactions.

and an Android-based host. As the current sport HR monitors are not appropriate for a precise measurement of the HRV [2], a portable device [6] acquires the ECG signal. This device has an Inertial Measurement Unit (IMU), able to provide information about the movement of the person that carries it. The communication between the acquisition system and the host is possible through a Bluetooth link.

The manuscript is organized as follows: Section II summarizes the acquisition system of HRV signal; Section III details the proposed algorithm for the automated allergy detection are detailed; Section IV introduces the Android-based host; Section V shows the obtained results; and finally, some conclusions are discussed in Section VI.

II. Acquisition System.

A Shimmer[6] device acquires the ECG signal during the

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978-1-5090-6244-7/17/$31.00 ©2017 IEEE

provocation tests. This device is small, light (23.6 grams), robust and with low power consumption, and it is able to store the measured data in its internal memory card and send it via Bluetooth. Furthermore, it is capable of measuring, storing and sending the acquired data related to the inertial sensors (3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer). An advantage of this system is that the patients can move freely with the device in their pocket.

This device uses a differential measurement of the ECG signal from a sensor network of three electrodes placed on the patient's chest with the Einthoven configuration [7].

A. HRV measurement.

In order to obtain de HRV signal, we use a QRS complex detection algorithm [8]. The output of this algorithm provides a signal (RR signal) composed of the distances in number of samples between each successive QRS complex. Finally, the HRV signal is obtained using the distances and the sampling frequency *Fs* (*Fs*=256Hz).

The performance of the QRS complex detection algorithm running in the Shimmer platform is successful. The results obtained with all the records of the MITDB database [9] provide a sensitivity of 99.73% and a positive predictivity of 99.77%.

III. AUTOMATED ALLERGY DETECTION.

As was stated, this work proposes a system through which it would be possible to warn the medical staff of the imminent onset of a food or drug allergic reaction during a provocation test. Before introducing the algorithm, it is worth to know how these tests are typically carried out in a hospital. All the results has been obtained through clinical trials in tow hospitals.

A. Provocation tests.

Nowadays, there is a process called provocation test to detect drug or food allergies. Fig. 5 summarizes a generic provocation test. The allergen is divided into different doses, and it is administered until an allergy reaction appears. When the allergen is finished, there is an observation period of 120 minutes. If nothing happens to the subject, neither in the next 24 hours, it is classified as non-allergic. In the case in which any symptom appears during the tests, the symptoms are treated, and the patient is classified as allergic. An objective of our platform is to try to reduce the duration of these observation periods, as well as to release the workload of medical staff, optimizing the evaluation of this test.

As can be deduced, this process is not risk-free, even with the constant observation of the medical staff, the allergic reaction can be of different levels of dangerousness: from the appearance of hives, or conjunctivitis, to breathing difficulties or, even, anaphylaxis. It is neither possible to know in advance which patient may suffer a more or less dangerous reaction, nor the kind of the reaction.

B. Allergic reaction detection algorithm.

A previous investigation [10] demonstrated that there is a relationship between changes on several patients' HRV signal

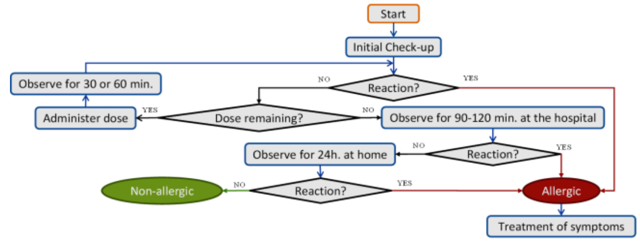

Fig. 5. Provocation tests flowchart.

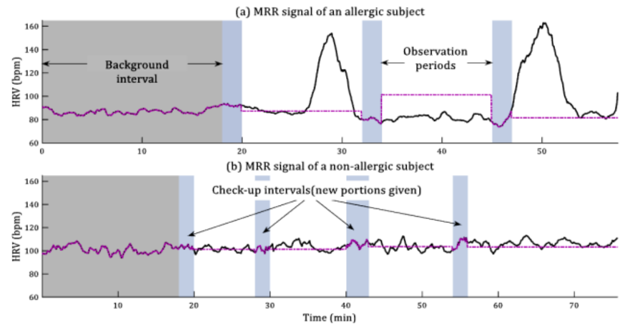

Fig. 6. MRR signal of an allergic (a) and a non-allergic (b) patients. Purple dotted line represents the mean value of the MRR signal during each "background" period, or MBG signal.

and a posterior occurrence of allergic reactions. Through a previous study carried out by the authors [1], we have confirmed this relationship. The study analysed 18 features of HRV, and it compared allergic subjects with non-allergic ones. After an in-depth analysis, the results demonstrated that the HRV mean feature (MRR) provides useful information regarding the physiological changes produced by an allergic reaction. Fig. 6 shows an example of the differences between the MRR signal (black solid line) of an allergic and a non-allergic patient during a provocation test. The background data has been shadowed with grey, and each one of the check-up periods (in which new doses of the allergen are given to the patients) has been colored with light blue.

As can be seen in the mean of HRV (see Fig. 6.a) of the patient who has an allergic reaction, the range and standard deviation are much higher in case of the allergic patient. We have proposed an algorithm [1] to detect these changes. Fig. 7 represents the flow chart of the designed allergy detection algorithm. It is composed of the following stages:

1. When an *i* Check-up ends, the mean of the MRR signal from *i*-1 Check-up of the test is computed (MBG), and an observation period starts. In the observation period the value of MBG keeps constant. If *i* is 1 (the first Check-up) MBG is computed from the beginning of the test.
2. During the observation period, the MRR signal is compared with the background data, i.e. the MBG value is subtracted from each new sample of the MRR signal. The result of the comparison is called NMRR.
3. Only for values of NMRR>0, the mean value of the NMRR signal has been computed, providing the result called MeanPeak. If the value of a MeanPeak is higher than a threshold (*Th*), it is considered an allergic reaction.

Our study [1] has verified with 24 patients that a suitable value for the threshold, for distinguishing between allergic and non-allergic, is 10 (*Th*=10).

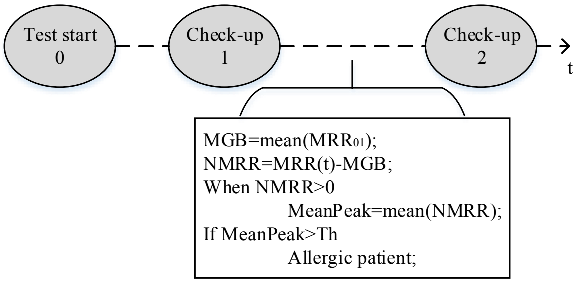

Fig. 7. Flowchart of the proposed allergy detection algorithm. MRR is the mean of HRV in the last 60 seconds; MGB is the mean MRR in the last period; NMRR is the subtraction of MRR and MGB; MeanPeak is the NMRR mean for values greater than zero; It is the alert threshold.

IV. ANDROID-BASED HOST.

As was introduced, the whole monitoring system is composed of the acquisition module (Shimmer) and an Android-based host that runs the allergy detection algorithm described in Section III. When the provocation test starts (see Fig. 5), the monitoring system has to initiate the acquisition of the ECG signal and to process it. As the test is carried out in the hospital, it is required that a clinician places the electrodes on the patient's chest and starts the host. After it, the acquisition module continuously sends the signals to the host, and the host should warn the clinicians in case that an allergy reaction could exist. For the implementation of the host we have selected a Samsung SM-T700 Tablet (1.9 GHz), at which the application is running.

A. Android Application Implementation.

The developed application, called Allergtronic, processes in real time the signals provided by the Shimmer during the provocation tests. The Android software is divided into three different processes (see Fig. 8). Some of the processes (threads) run in parallel, avoiding the collapse of the user interface and reducing the execution time of the application. The behavior of each thread is as follows:

- Thread 1: This is the main thread, and it controls the graphical user interface and drives the Bluetooth connection.
- Thread 2: it runs the allergy detection algorithm, and continuously checks the correct connection of the acquisition module, which provides the ECG. It calculates the parameter related to the HRV described in Section III to warn the clinicians if necessary. The information generated at this thread is sent to the first one in order to be graphically displayed.
- Thread 3: it is responsible for saving the information in a memory card.

B. Graphical User Interface.

This section describes the user interface. This interface has been designed following a standard provocation test (see Fig. 5), and trying to be simple and intuitive for its clinical use. Fig. 9 shows the flowchart of the user interface. We have tried to imitate the process that the clinicians follow in the hospital

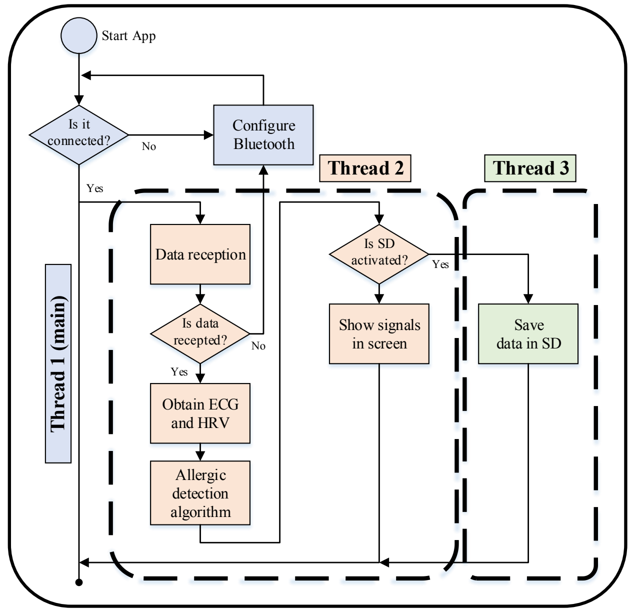

Fig. 8. Allergtronic flowchart.

during the provocation tests (including the patient information that has to be registered).

Then, initially the host checks the correct connection to the Shimmer, otherwise it allows to configure a manual connection. After it, the patient set up is carried out (number of patient, gender, age, type of test, type of dose, number of expected doses, etc.). When the clinician press the "Start test", the monitoring system starts working. Anytime there is a new dose, it has to be registered by using the interface. The test finishes when is pressed the "End test" button.

If during the provocation test there is a possible allergy reaction according to the algorithm of Fig. 7, the application shows an alarm to warn the medical staff. Fig. 10 shows the user interface with the information related to a patient that is lactose allergic. The application shows three graphs: the ECG, the HRV and the result of the allergy detection algorithm. In this case, it is displayed when the algorithm detects an allergy reaction (in this case there are two alarms).

V. RESULTS

The allergy reaction detection algorithm has been tested during a clinical trial in the Guadalajara University Hospital (Spain). During this data collection, the ECG signal for 154 patients have been recording, from which 147 were valid. The rest of the signals were discarded due to different problems (mainly wrong electrodes attachment). Table 1 shows the obtained results with the proposed algorithm, reaching a success rate close to 90%.

Total		**Clinical result**		**Test result**		**Success rate**
		P*	**N****	**P**	**N**	
147 subjects	**28 children**	8	20	7	19	92.85%
	119 adults	7	112	3	102	88.23%

* P: Number of Positives;
** N: Number of Negatives.

Tab. 1. Results of allergy detection algorithm.

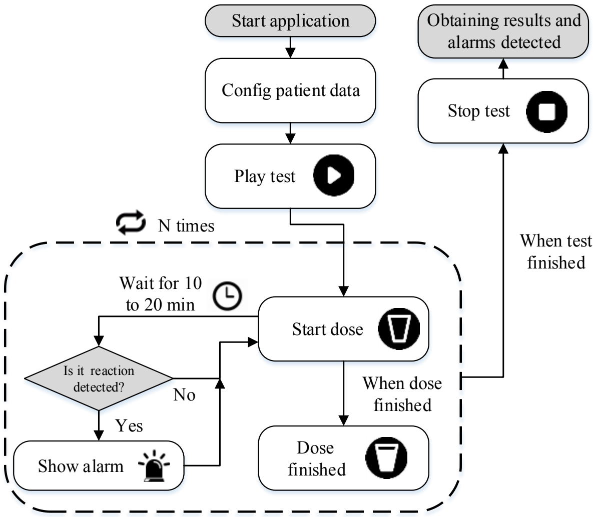

Fig. 9. User interface flowchart.

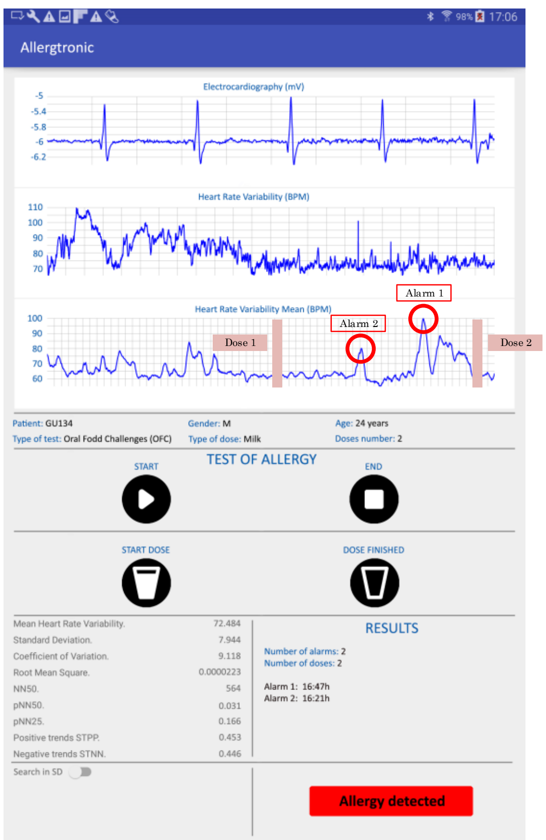

Fig. 10. User interface. Information of a provocation test.

Thanks to the proposed system, the duration of the tests has been reduced for the allergic subjects from a mean length of 1 hour and 16 minutes, to only 48 minutes; and the number of doses from 3.93 to 1.61.

VI. Conclusions

This paper describes the design of a portable monitoring system for the early detection of allergic reactions in patients undergoing allergy provocation tests. The monitoring system is mainly based on an Android platform, which not only runs the allergy detection algorithm designed by the authors but also generates real-time alarms to warn the clinicians when a potential allergy reaction is detected.

The success rate is 92.85% (of 28 subjects) in case of children, and 88.23% (of 119 subjects) in case of adults. In addition, this proposal helps reducing the duration of the test for the allergic subjects, increasing the safety of the patients.

As a future work, it is proposed the use of the IMU data provided by the acquisition module (Shimmer) for two reasons. Firstly, it helps to locate the patients within the hospital providing then more information to the medical staff; and secondly, the acceleration data can be used to reduce false positives (the HRV can be modified by the patients' movement as well). Finally, it is necessary to extend the clinical trial in order to get enough patients to conclude how good the performance of the proposed system is.

Acknowledgment

This work has been supported in part by Spanish Ministry of Economy and Competitiveness through the TARSIUS project, TIN2015-71564-C4-1-R; and thanks to the National Youth Guarantee System Administrative, Unit of the European Social Fund (Order ECC / 1402/2013).

References

[1] Raquel Gutiérrez Rivas, "Real-Time Early Detection of Allergic Reactions based on Heart Rate Variability," University of Alcalá, National University of Ireland, Cork, 2016.

[2] V. Jeyhani, S. Mahdiani, M. Peltokangas, and A. Vehkaoja, "Comparison of HRV parameters derived from photoplethysmography and electrocardiography signals," in *2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 2015, pp. 5952–5955.

[3] J. Parak, A. Tarniceriu, P. Renevey, M. Bertschi, R. Delgado-Gonzalo, and I. Korhonen, "Evaluation of the beat-to-beat detection accuracy of PulseOn wearable optical heart rate monitor," in *2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 2015, pp. 8099–8102.

[4] N. Twomey, "Digital Signal Processing and Artificial Intelligence for the Automated Classification of Food Allergy.," National University of Ireland, 2013.

[5] G. G. Berntson, J. T. Bigger, D. L. Eckberg, P. Grossman, P. G. Kaufmann, M. Malik, H. N. Nagaraja, S. W. Porges, J. P. Saul, P. H. Stone, and M. W. van der Molen, "Heart rate variability: origins, methods, and interpretive caveats.," *Psychophysiology*, vol. 34, no. 6, pp. 623–648, 1997.

[6] Shimmer, "SHIMMER (Sensing Health with Intelligence, Modularity, Mobility, and Experimental Reusability)." .

[7] S. S. Barold, "Willem Einthoven and the Birth of Clinical Electrocardiography a Hundred Years Ago," *Card. Electrophysiol. Rev.*, vol. 7, no. 1, pp. 99–104, 2003.

[8] R. Gutierrez-Rivas, J. J. Garcia, W. P. Marnane, and A. Hernandez, "Novel Real-Time Low-Complexity QRS Complex Detector Based on Adaptive Thresholding," *IEEE Sens. J.*, vol. 15, no. 10, pp. 6036–6043, Oct. 2015.

[9] G. B. Moody, R. G. Mark, "The impact of the MIT-BIH Arrhythmia Database", *IEEE Eng. Med. Biol. Mag.*, vol. 20, no. 3, pp. 45–50, 2001.

[10] N. Twomey, A. Temko, J. O. Hourihane, and W. P. Marnane, "Automated Detection of Perturbed Cardiac Physiology During Oral Food Allergen Challenge in Children," *IEEE J. Biomed. Heal. Informatics*, vol. 18, no. 3, pp. 1051–1057, May 2014.