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BRIEF REPORT

A Biotechnological T-Shirt Monitors the Patient's Heart during Hemodialysis

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Abstract

Uremic patients are characterized by a "pro-arrhythmic substrate." Arrhythmia appearance during hemodialysis (HD) is an unexpected event with a high incidence of mortality and morbidity and difficult to record in patients repeatedly checked using electrocardiogram (ECG). Furthermore the carrying out of this important examination by classical devices during HD is uncomfortable and sometimes stressful for the patient. It may be very useful to monitor the patient's cardiac activity during the whole HD session. We tried to overcome these difficulties using Whealthy® (Wearable Health Care System), a wearable system in a T-shirt composed of conductors and piezoresistive materials, integrated to form fibers and threads connected to tissular sensors, electrodes, and connectors. ECG and pneumographic impedance signals are acquired by the electrodes in the tissue, and the data are registered by a small computer and transmitted via GPRS or Bluetooth.

Keywords: arrhythmias, hemodialysis, cardiovascular risk, ECG, Bluetooth

INTRODUCTION

Arrhythmias and Hemodialysis

The increased cardiovascular risk of patients undergoing hemodialysis (HD) compared with the general population is due to both general factors and specific problems related to renal failure.[1] HD influences the cardiovascular system modifying the chemical–physical characteristics of body fluids, such as pH, temperature, and plasma electrolytic concentration.[2] Variations in calcium and potassium, in both the plasmatic and intracellular environment, play an important pathogenetic role in the onset of arrhythmias during HD[3,4] that, together with other serious complications including sudden death, contribute to the increase of the mortality rate in these patients.[5,6] Electrocardiography is a good tool to evaluate these conditions. Supraventricular and ventricular premature heartbeats, S–T segment alterations, and atrial fibrillation are related to changes in the electric potential of myocardiocyte membrane.[7–9] It is also important to evaluate the duration and homogeneity of ventricular repolarization. The QT interval and the QT interval corrected for the heart rate (QTc) reflect the duration of ventricular depolarization and repolarization; the QT dispersion (QTd) and the QTc dispersion (QTcd), defined as the difference between the maximum and minimum QT and QTc, respectively, represent the variability of ventricular repolarization and are significantly increased during HD. These elements are actually considered as markers of cardiovascular risk.[10] Recently, we have reported a reduction in QTc interval after hemodiafiltration (HDF); it was inversely correlated to the plasmatic calcium variations. This finding confirms the data by Nappi and coworkers and underlines the importance of avoiding dialysate solutions with very low calcium concentration.[11,12] The rapid removal of potassium in the early phases of the hemodialytic session is associated with significant electrocardiogram (ECG) alterations. The comparison between two different dialysis techniques, HDF and HDF with variable potassium concentration (HDFk), allowed us to demonstrate that the risk of arrhythmias is lower with HDFk. The advantage of this technique is related to the use of solutions with high potassium concentration during the first part of the dialytic session: this creates a low blood–dialysate gradient and a gradual removal of potassium during the entire session.[13,14] We can then conclude that HD induces ECG alterations related to plasmatic electrolytic variations, which are particularly dangerous in "critical" patients, such as heart patients and diabetics.

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HISTORY OF DEVELOPMENT

Real-Time ECG Recording during Hemodialysis with a Wearable Health Care System

It may be very useful to evaluate the heart activity during the HD session. The application of a large-scale ECG monitoring during dialysis, however, is not simple because of the structural difficulties and the work overload of doctors and nurses in hospital wards. Standard Holter ECG (24 h continuous recording of 2–3 ECG leads) is actually a simple recorder that needs to be put on and then removed in hospitals or clinics. Data analysis is offline and only a delayed medical response can be generated when abnormalities are detected. These systems are therefore used to reach a nonurgent diagnosis (e.g., verify that palpitations referred by a patient are due to cardiac arrhythmias), yet they are not practical when medical data have to be obtained more frequently.

Moreover, the patient should be connected to complex instruments that may further worsen his quality of life. These considerations have encouraged us to look for a noninvasive system to collect biomedical signals and to identify the electrophysiological changes that occur in the patient's body. During HD, these signals are very weak and they are disturbed and distorted by noise; these problems increase if we use wearable systems, in which electrodes consist of metallic or polymeric tissues; the patient's movements represent a further confounding element. We overcame these difficulties using Whealthy® (Wearable Health Care System; Smartex s.r.l., Prato, Italy), the prototype of a project supported by the European Commission, to monitor ECG during HD in heart patients.

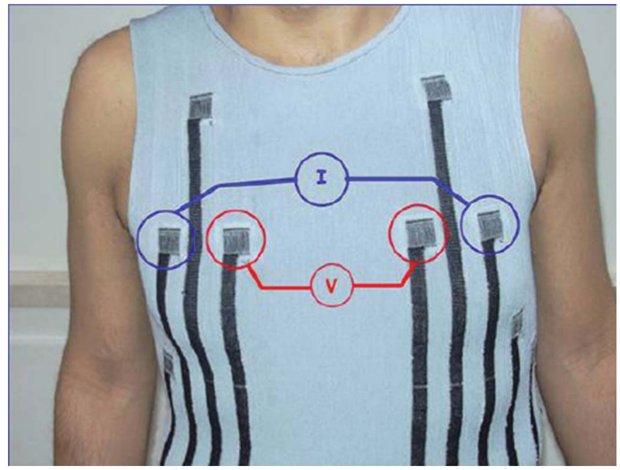

Figure 1. T-shirt (Whealthy®) able to acquire simultaneously five ECG leads, heart rate, and respiratory activity with main tissular sensors, electrodes, and connectors.

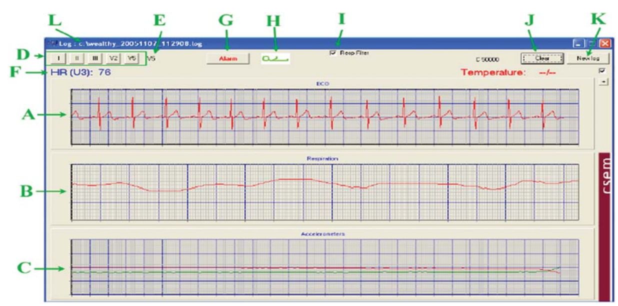

Figure 2. Screen sample view of biomedical parameters wireless acquired from Whealthy® shirt and elaborated by a PC through proper software. (A) ECG signal, (B) respiratory system, (C) signals of vertical and horizontal acceleration, (D) ECG lead selection (D1, D2, D3, V2, V5), (E) selected lead, (F) heart rate, (G) button for the generation of alert signal to PPU, (H) PPU position (standing or lying), (I) respiratory signal filter, (J) button for clear acquired data, (K) button for acquire new data, and (L) file name.

DESCRIPTION AND CLINICAL ROLE

Whealthy consists of a T-shirt, composed of conductors and piezoresistive materials, integrated to form fibers and threads connected to tissular sensors, electrodes, and connectors (Figure 1).

ECG and the pneumographic impedance signals are acquired by the electrodes in the tissue, while two piezoresistive sensors distinguish the thoracic activity from the abdominal activity: the first is located near the lower part of the sternum and the second near the umbilicus to register the pattern of thoracic and abdominal breathing. The use of impedance pneumography measurements reduces the errors due to the patient's movements, phonation, and costal expansion not related to breathing activity. All the signals are acquired simultaneously, so it is possible to perform a comparative control of the cardiopulmonar activity. The data are registered by a small computer (150 g) that receives the information from the sensors, produces electricity in two electrodes for the impedenziometric measurement, analyzes ECG data through an algorithm, and transmits the data via GPRS or Bluetooth (Figure 2).

In the system we used, the Bluetooth signal is transmitted to an electronic board Samsung Q1, an easily handled instrument with great technological potentialities (10/100 Ethernet, 802.11bg wireless and Bluetooth 2.0 (EDR)). The data can then be analyzed to prevent a worsening of the patient's health conditions. ECG can be printed as classical ECG or can be read on the screen. Development of PC software will allow having an automatic "diagnosis" with an alarm in pathological conditions. Without connection threads our patients can move freely during the dialytic session and undergo electrocardiographic controls even at the end of the treatment, in hospital or at home (Figure 3). This equipment then receives ECG signals from the T-shirt and memorizes and elaborates them, helping the nephrologist in cardiologic diagnosis and therapy by means of dedicated and expert software.

Figure 3. A patient on hemodialytic treatment with Whealthy®, the Wearable Health Care System wireless connected to a mobile PC.

CONCLUSION

In conclusion, we believe that the use of the Whealthy system can significantly improve the quality of life of critical hemodialyzer patients affected by cardiopulmonary diseases: nephrologists can control the patient's cardiac and respiratory activity minute by minute, administering preventive drug therapy and changing dialytic parameters. Far from considering Whealthy only as an application separate from the dialysis machine, our project aims to insert it as one of the several "auto feedbacks" that characterize the new generation of dialysis machines, making real the dream of a complete "artificial kidney."

***Declaration of interest*:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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