Chapter 17
A Hypotension Surveillance and Prediction System for Critical Care

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ABSTRACT
The sudden fall of blood pressure (hypotension) is a common and serious complication in medical care. In critical care patients, hypotension may induce severe or even lethal events. Moreover, recent studies report an increase of mortality in critical care patients. By predicting hypotension (HT) in advance, medical staff can take action to minimize its effects or even avoid its occurrence. Typically, most medical systems have focused on monitoring current patient status, rather than predicting a patient’s future status. Therefore, predicting HT episodes in advance remains a challenge. In this chapter, the authors present a solution for continuous monitoring and prediction of HT episodes, using Heart Rate (HR) and mean Blood Pressure (BP) biosignals. They propose an architecture for a HT Predictor (HTP) Tool, presenting a set of applications and a real-time database capable of continuously storing, and real-time monitoring all patients’ historical HR and BP data. The tool is able to efficiently alert both probable and detected occurrences of HT episodes for each patient for the following 60 minutes. Additionally, the system promotes medical staff mobility, by taking advantage of mobile personal devices such as mobile phones and PDAs, optimizing human resources. Finally, an experimental evaluation on real-life data from the well-known Physionet database shows the efficiency of the tool, outperforming the winning proposal of the Physionet 2009 Challenge.

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INTRODUCTION

Blood Pressure (BP) is the force exerted by circulating blood on the walls of blood vessels, and is one of life’s main vital signs. BP is generated by the heart when it pumps blood into the arteries, and is regulated by the response given by arteries to the flow of blood. Hypotension (HT) occurs when there is an abrupt fall of BP leading to below normal values, so low it causes symptoms or signs due to the low flow of blood through the arteries and veins. When the blood flow is too low to deliver enough oxygen and nutrients to vital organs such as the brain, heart and kidney, they do not function normally and can get permanently damaged. Hypotension is classified as a common complication in patients with critical care needs, such as hemodialysis (Daugirdas, 2001).

Hemodialysis is the combination of ultrafiltration of fluid excess and the clearance of solute waste products such as urea by diffusion. This treatment is accompanied by a wide variety of complications. Despite all technical improvements, the most frequent complication is intradialytic hypotension (IDHT), occurring in up to 20% of dialysis sessions (Straver, 2005). IDHT occurs when our normal biological compensatory mechanisms cannot cope with the removal of intravascular fluid in a short period of time in a specific patient. Negative effects of IDHT are the patient’s discomfort and decrease of hemodialysis efficacy due to interventions such as interruption of dialysis and the need for intravenous infusions. IDHT can induce other severe complications such as serious heart, endocrine or neurological and can even lead to the patient’s death. Moreover, a recent study reports an increase of mortality in HT prone hemodialysis patients (Shoji, 2004). Therefore, reducing HT episodes in critical care patients remains a challenge.

Typically, most medical systems store biosignal data for a short time, in order to monitor the patient’s most recent vital signs, and usually do not forecast or issue an alert concerning a patient’s predictable hazardous situation (Bai, 2006). Therefore, most medical systems are typically focused on detecting the current health status of a certain number of vital signs, rather than attempting to predict immediate future trends on any of those features. Thus, standard methods are mainly centered on feature detection rather than feature prediction.

The main issues concerning useful time prediction and detection of HT episodes evolve around two main aspects: 1) How can we efficiently store the biosignal data that is needed in a continuous manner and enable real-time hypotension monitoring and prediction; and 2) Which are the algorithms to be used for efficient hypotension detection and prediction. The Physionet Challenge 2009 (Physionet C, 2009) promoted solutions for predicting HT patient status. The paper (Henriques, 2009), using a neural network approach, was the challenge’s winner, scoring 47 correct predictions out of 50 for the whole event. Our work continues the former research, proposing a full HT monitoring, detecting and predicting medical care system that also promotes medical staff mobility. Regarding efficient real-time biosignal data integration, we present a database for storing all patients BP and heart rate (HR) data. Using this data, we have developed a new HT prediction technique, working with a set of applications capable of monitoring each patient’s status and efficiently predicting if a hypotensive episode will occur during the next 60 minutes.

Our proposal allows medical staff to continue carrying out their daily tasks without needing to remain staring a fixed monitor for continuously watching over a patient, because we provide applications able to run on a mobile phone or PDA, issuing a real-time alert every time a hypotensive episode is detected or predicted. This enables continuously monitoring the status of a patient at all times (on a 24/7 schedule) without needing to be physically present, promoting medical staff mobility and allowing them to continue carrying out their work unrestrained by patient critical