Chapter 12
Personal Health Systems for Diabetes Management, Early Diagnosis and Prevention

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ABSTRACT

This chapter aims at the presentation and comparative assessment of tools and methodologies used for the development of Personal Health Systems (PHSs) for diabetes management, early diagnosis and prevention. Medical decision support systems such as glucose prediction models, risk assessment models for long-term diabetes complications, models for early diagnosis of diabetes and closed-loop glucose controllers along with integrated systems for diabetes management are described. The outcomes of a wide range of research studies demonstrate the feasibility of providing safe, reliable and cost-effective solutions towards improving patients' quality of life through the application of PHSs. Specific limitations that prevent these systems from being fully adopted in clinical practice are highlighted, while challenges and future research directions are summarized.

INTRODUCTION

Diabetes Mellitus (DM) is a group of chronic metabolic diseases characterized by elevated blood glucose levels for a prolonged period. The deregulation of glucose metabolism is due to either the insufficient insulin secretion from the pancreatic cells or impaired response of the body cells to insulin. DM is broadly classified into three main categories:

1. **Type 1 Diabetes Mellitus (T1DM)**: T1DM is an autoimmune disease caused by the destruction of insulin-producing beta cells of the pancreas resulting in the absence of insulin secretion. T1DM is usually diagnosed in children and young adults and accounts for only 5% of patients with diabetes.

2. **Type 2 Diabetes Mellitus (T2DM)**: T2DM is characterized by, either or both, insulin resistance and relative insulin deficiency. It is the most common form of diabetes accounting for at least 90% of all cases of diabetes.

3. **Gestational Diabetes Mellitus (GDM)**: GDM is characterized by high blood glucose levels during pregnancy. GDM accounts for one per 25 pregnancies worldwide. GDM usually disappears after pregnancy but it is a risk factor, for both the mother and the child, to develop T2DM in the future. Approximately half of women with a history of GDM develop T2DM within five to ten years after delivery.

DM has severe short-term and long-term complications. In particular, diabetic ketoacidosis, and hyperglycemia hyperosmolar state, are acute episodes, which may lead to diabetic coma if not treated promptly and properly. Moreover, severe hypoglycemic episodes which are caused by overdoses of administered insulin, may lead to the lost of consciousness. The excess glucose circulating through the body in the blood stream over time leads to damage of blood vessels and severe long term mortality related complications such as cardiovascular disease, diabetic neuropathy, and diabetic retinopathy.

According to the International Diabetes Federation (IDF) (2013), 382 million people (8.3% of adults) suffer from DM worldwide, while 175 million people with DM are undiagnosed. By 2035, it is estimated that 592 million people will have DM. In 2013, 5.1 million of deaths were attributed to DM while at least USD 548 billion dollars of health expenditure were caused from DM, which corresponded to a percentage of 11% of the total health spending on adults. According to the outcomes of the Diabetes Control Complications Trial, intensive glycemic control, reduces the long-term diabetes complications in T1DM (The Diabetes Control and Complications Trial Research Group, 2003). Moreover, several studies have investigated the importance of tight glycemic control for protection against the incidence of microvasclular and cardiovascular disease in T2DM (Giorgino, Leonardini, & Laviola, 2013). Intensive glycemic control involves regular glucose measurements and exogenous insulin administration, in case of insulin treated patients. To this end, latest technological advances have led to the development of Continuous Glucose Measurement Systems (CGMS) able to provide the information of glucose levels every 1 *min* or 5 *min*, and subcutaneous insulin infusion pumps (Klonoff, 2005).

The high prevalence of DM, and the rapidly growing number of patients with DM, along with the rising costs of care, the predictable number of deaths and medical errors, poses the need to move from a health system that focuses on the disease to a health system that focuses on personalized care. Optimal management of diabetes requires deep understanding of the risk factors associated with the disease, early diagnosis and treatment of the disease before the occurrence of complications, and tight glycemic control. Toward this direction, several technological advances in the fields of sensors for physiological parameters measurement and drug delivery systems coupled with advanced Information and Communications Technology (ICT) that enable efficient monitoring, data presentation, decision support, and social networking, make feasible the development of personal health systems for the remote monitoring and management of patients with DM. Intelligent systems for multi-parametric biomedical data analysis (such as physiological measurements, genetic data, medical images, laboratory examinations, activity, lifestyle and data from the surrounding environment) play a crucial role in personal health systems, focusing on the processing and interpretation of the data for accurate and timely alerting, signalling of risks, supporting clinical decisions and empowering patients for self-managing their disease.

The development of Personal Health Systems (PHS) for DM management, early diagnosis and prevention, attracts great interest from the international research community leading to a wide range

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