Computational Methods for the Early Detection of Diabetes

Herbert F. Jelinek
Charles Sturt University, Australia

David J. Cornforth
University of New South Wales, Australia

INTRODUCTION

The incidence of diabetes is increasing, and is expected to exceed one million people in Australia by the year 2010. Diabetes is currently diagnosed after the onset of symptoms. At this stage, detection of complications is a key intervention point in reducing the associated personal and community burden. These include eye, heart, kidney, and foot disease, which in many instances can be treated with good outcomes, provided the disease process is recognized early. In Australia, both national and state governments acknowledge the disadvantage faced by rural people in availing themselves of all aspects of diabetes management, from screening to regular assessment, education and health care (Colagiuri, Colagiuri, & Ward 1998). Therefore, the challenge that is the focus of this article is the early detection of diabetes complications associated with vision and cardiac function, with the eventual aim of providing a screening service that can be used in a rural or regional environment.

BACKGROUND

Complications associated with diabetes often remain undetected for quite some time, especially in rural regions, but are often what alerts health care providers to the presence of diabetes. Vision loss, cardiovascular disease, and foot amputations are the most often occurring outcomes of diabetes. Early detection of blood vessel changes associated with retinopathy, cardiovascular disease, and foot complications is important for timely treatment, to prevent or delay the occurrence of these complications and improve the quality of life for individuals with diabetes. Regular health screening that includes eye and cardiac function assessment has the potential to reduce the high costs on the health care system associated with diabetes, and to reduce the disparity in health care between rural and urban communities by providing timely feedback to those at risk.

Currently, regular screening provides an opportunity to discover people with unidentified diabetes and with subclinical eye and heart complications. Extrapolation from data obtained from eye health initiatives indicates that interventions that relieve or prevent complications associated with diabetes are highly cost effective (Lee, Lee, Kingsley, Wang, Russell, Klein, & Warn, 2001).

Universal screening is both feasible and cost effective. It delays complications, and younger patients have a longer time to benefit from early identification. In spite of this, diabetes screening is far from universal, especially among rural and regional populations. However, recent reductions in the cost of health technology and an increase in the availability of computing equipment, coupled with advanced data processing techniques, offer new opportunities. These include the ability to detect complications earlier, make screening faster, more accurate and cheaper, and to remove access barriers faced by those in rural and regional communities. This article focuses on two aspects of screening that could benefit from automation using computational techniques: diabetic retinopathy (DR), and cardiovascular disease.

DR is a condition in which the retina has suffered damage due to the complications of diabetes. DR could be significantly reduced by simplifying the procedure used to identify the condition and ensuring that early eye examinations become routine for diabetic patients. Damage to the eye associated with DR is the commonest cause of blindness in the working age population in developed countries. Yet, 98% of people with vision loss can be treated effectively provided the pathology is detected early (Lee et al., 2001). Automated assessment of retinal health allows community screening programs to be offered and operated effectively, utilizing community health professionals.

Cardiovascular disease includes a range of diseases, of which coronary artery disease (CAD) is the single most common cause of death in the western world. Cardiovascular complication is associated with diabetes, and on its own is the most common cause of death (Mathers & Penm, 1999). Cardiovascular disease affecting the larger blood vessels is a major complication of diabetes. People with diabetes are two to four times more likely to develop cardiovascular disease, and their prognosis is not as good as those without the disease. Cardiac autonomic neuropathy (CAN) is part of the cardiovascular disease spectrum, in part caused by CAD, which leads to reduced oxygenation of the nerves regulating the cardiac rhythm. The resulting morbidity and mortality can be reduced with regular screening and early recognition of nervous system damage affecting cardiac function in people with diabetes, which allow better treatment intervention.

Electrocardiology is still regarded as the most commonly used procedure for the assessment of cardiac function and identification of heart disease, and is utilized by numerous health care practitioners. The 12-lead electrocardiograph (ECG) is the kind of equipment most often used in regular general practice. In community health care, outreach nurses do not have the in-depth training to determine risk of a potentially dangerous cardiovascular condition, based on signs and symptoms, and are most often familiar with three-lead recordings. ECG interpretation is usually carried out by a specialist.

Screening for both cardiovascular disease and DR in rural areas is difficult because of health care barriers such as geographical isolation, the cost of visits to specialists, and the lack of cardiologists and ophthalmologists.

COMPUTATIONAL METHODS FOR THE EARLY DETECTION OF DIABETES IN A RURAL CONTEXT

Advances in computational methods that may be of use in rural settings involve two main areas: DR, and heart rate variability (HRV). Both of these rely on the fact that diabetes affects the cardiovascular system. Both aim to provide methods that can be applied easily and cheaply in a rural setting.

Analysis of Diabetic Retinopathy

The assessment of retinopathy has been enhanced by the ability of regional clinics to make quality photographs of the retina that can be then sent to remote ophthalmologists for assessment. This has recently been expedited using digital photography and improvements in digital communication. The best quality images are obtained using fluorescein photography, where the contrast is enhanced by using a dye injected into the bloodstream. This, however, is invasive, and much research has been conducted into processing of nonfluorescein color images using computational techniques.

The scope of DR covers a wide range of pathologies that are amenable to automated identification including:

- Microaneurysms (Jelinek, Cree, Worsely, Luckie, & Nixon, 2006; Cree, Olson, McHardy, Forrester, & Sharp, 1996).
- Hard exudates and cotton wool spots (Dua, Kandiraju, & Thompson, 2005).
- Haemorrhages (Singalavanija, Supokavej, Bamroongsuk, Sinthanayothin, Phoojaruenchanachai, & Kongbunkiat, 2006).
- New vessel growth (Soares, Leandro, Cesar, Jelinek, & Cree, 2006).
- Arteriolar narrowing and venous dilatation (Wong, Shankar, Klein, Klein, & Hubbard, 2005).

Automating the assessment of changes in the retina can be carried out using mathematical techniques. These techniques can be applied to the estimation of blood vessel diameter changes and quantify the appearance of microaneurysms and haemorrhages in the early stages of retinopathy, as well as new vessel growth in the advanced stages of DR. Of interest has been the correlation between blood vessel diameter changes in the eye that is not only associated with diabetes, but is also an early indicator for cardiovascular disease and stroke (Wong et al., 2005). For the automated assessment of most of these, the optic disk needs to be identified. This facilitates, for example, macula location, false positive localization of hard exudates, and vessel tracking.

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