Chapter 9
Development of a Fuzzy Logic-Based Model for Monitoring Cardiovascular Risk

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ABSTRACT

Cardiovascular diseases (CVD) are top killers with heart failure as one of the most leading cause of death in both developed and developing countries. In Nigeria, the inability to consistently monitor the vital signs of patients has led to the hospitalization and untimely death of many as a result of heart failure. Fuzzy logic models have found relevance in healthcare services due to their ability to measure vagueness associated with uncertainty management in intelligent systems. This study aims to develop a fuzzy logic model for monitoring heart failure risk using risk indicators assessed from patients. Following interview with expert cardiologists, the different stages of heart failure was identified alongside their respective indicators. Triangular membership functions were used to fuzzify the input and output variables while the fuzzy inference engine was developed using rules elicited from cardiologists. The model was simulated using the MATLAB® Fuzzy Logic Toolbox.

INTRODUCTION

Cardiovascular diseases (CVD) are top killers, causing about 12 million deaths throughout the world. The World Health Organization (WHO) alongside other organizations is implementing a more integrated approach to the prevention of cardiovascular diseases and the risk factors that contribute to them (World Health Organization, 2015). The related diseases include coronary heart disease (heart attacks), cerebro-

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vascular disease (stroke), raised blood pressure (hypertension), peripheral artery disease, rheumatic heart disease, congenital heart disease and heart failure. Cardiovascular disease is the number one cause of death worldwide (Mathers *et al.*., 2003; Murray & Lopez., 1996). It covers a wide array of disorders, including diseases of the cardiac muscle and of the vascular system supplying the heart, brain, and other vital organs. CVD causes up to 65 percent of all deaths in developed and developing countries of people with diabetes (Geiss *et al.*., 1995). Cardiovascular disease results in severe illness, disability, and death alongside with narrowing of the coronary arteries which results in the reduction of blood and oxygen supply to the heart which leads to coronary heart disease (CHD) (Lakshmi *et al.*., 2013).

Heart failure is a serious condition resulting in the hospitalization of persons older than 65 years with significant morbidity and mortality rates in both men and women. Although there has been reduction in the in-hospital mortality rate over the last 15 years, there has not been any major improvement in the 30-day mortality rate and hospital re-admission rates have also increased (Bueno *et al.*., 2010; Heidenreich *et al.*., 2010). The huge impact of hospitalizations due to heart failure on health care systems has led to research motivated with identifying patients at high risk of heart failure in order to target them for intense therapy or move them on to palliative care if necessary. It is difficult to accurately identify those patients with high risk of death as current methods of risk stratification which lacks both sensitivity and specificity. According to Danaei *et al.*, (2009), preventing hospital readmission is the most important factor in reducing cost and resource use for care of heart failure patients. Although re-hospitalization rates after a heart failure admission are high, there is considerable variability between the factors associated with 30 day readmissions rate. Jencks *et al.* (2009) indicate that improvements in readmission rates are possible at a national level, suggesting that standardization in discharge interventions should reduce readmissions. Standardization would be of benefit because 20-40% of re-hospitalizations (i.e., readmission to any hospital, not necessarily the same hospital as a prior admission) occur to other hospitals and are essentially lost to follow-up at the Local Government level and third party data.

Table 1 gives a description of the different stages of heart failure and their respective associated description. Heart failure is classified into four (4) groups called stages, namely: Stages A, B, C and D. Stage A is a stage at which a person is at risk of heart failure but without structural heart diseases or symptoms of heart failure. This is the most important stage of this study for an individual may not necessarily have symptoms but rather have certain response to the risk factors. Stage B is the stage at which the individual is already experiencing structural heart disease but without symptoms and signs of heart failure. At this stage, the disease can be shown to be present only after a number of tests have been performed by the individual. Stage C is a stage in which individual has both structural heart disease but with prior or current symptoms of heart failure evident after the series of test taken by the patient; and Stage D is a stage at which the patient is experiencing treatment-resistant heart failure which remains persistent despite treatment and thus leads to special intervention procedure.

It is generally believed that predictive modeling of disease may reduce hospitalization of patients (HealthLeaders, 2010) and thus a means of keeping patients away from returning to hospital facilities unnecessarily (HealthLeaders, 2012). A predictive model has potential to identify risk of being hospitalized (Russel *et al.*, 2010) and it is an intervention method in the care of patients who have a moderate level of hospitalization risk. It is an effective method of producing important and meaningful changes in the quality of care. The integration of computing platforms and wireless communications technologies in healthcare systems has enhanced the quality of health care for millions of people around the globe (Yan *et al.*, 2005). It has improved the management of medical supplies, medical diagnoses, patient record administration and health care service delivery. Follow-up of in-ward patients' vital signs' status