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The utility of Zero Effort Technology in monitoring and mitigating heart failure in senior patients



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Heart Failure (HF) is currently a global pandemic affecting an estimated 26 million people worldwide in 2014¹. Hospitalized heart failure (HFF) is reportedly the leading cause of hospitalizations in Europe, the United States (over 1 million hospitalizations in both regions)¹ and Canada (305,000 Canadian hospitalized)². HFF costs the Canadian economy more than \$20.9 billion CAD in hospital costs, physician services, lost wages and decreased productivity². The disease has a higher prevalence rate in seniors with a reported 23% of Canadian seniors affected by the disease in 2009. Over half of Canadians suffering from the disease were predisposed with two major factors namely; hypertension and sedentary behaviour³. HF is the final stage in the cardiovascular disease continuum and is a culmination of a chain of events as depicted below by *Figure 1*⁴.

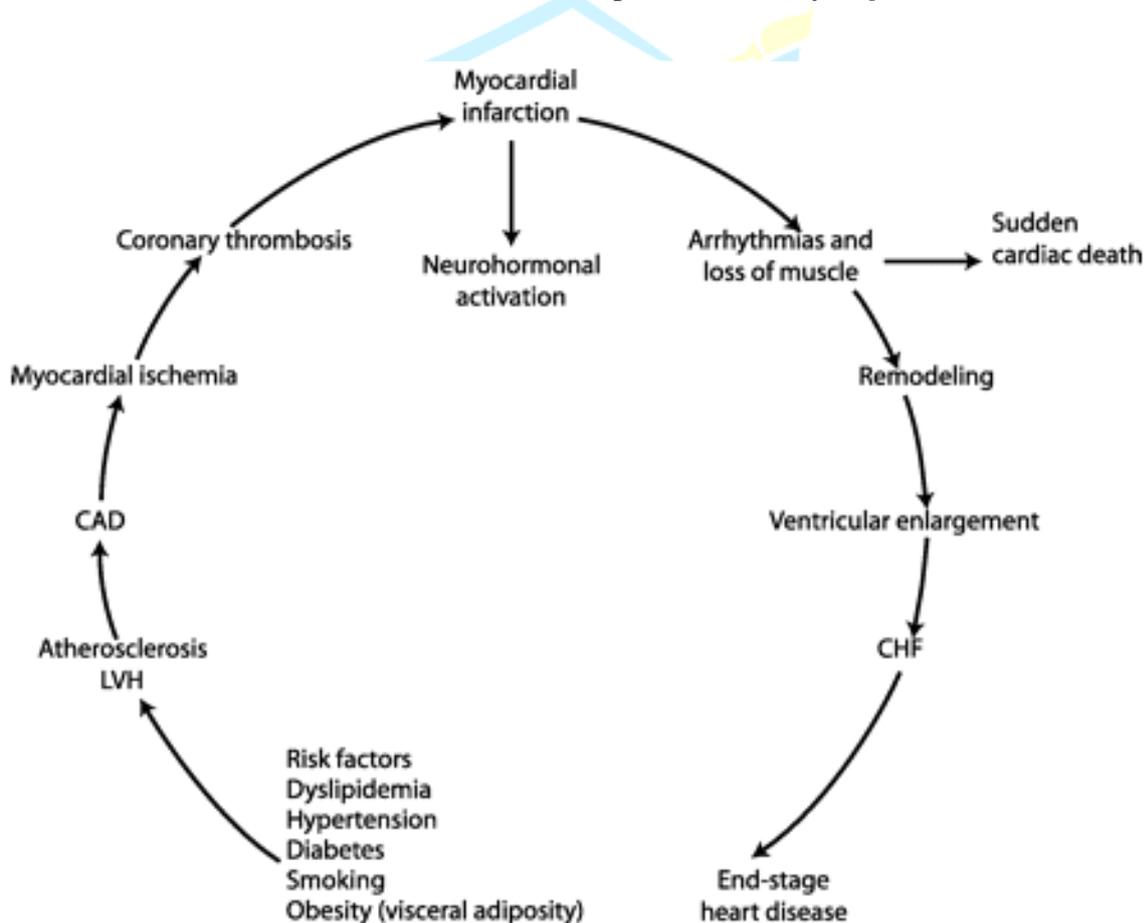


Figure 1. The cardiovascular disease continuum. LVH=left ventricular hypertrophy; CHF=congestive heart failure⁴.

The disease is characterized by abnormalities in cardiac structure or function leading to the failure of the heart to sufficiently deliver enough oxygen necessary to facilitate the activities of the metabolizing tissues of the body. The disease is clinically ascertained when patients develop symptoms such as breathlessness, paroxysmal nocturnal dyspnoea, orthopnoea, reduced exercise tolerance, fatigue and ankle swellings. Clinical signs leading to disease diagnosis also include hepatojugular reflux, cardiac murmur, third heart sound (gallop rhythm), laterally displaced apical impulse, pulmonary crackles, displaced apex beat and elevated jugular venous pressure⁵. Vital signs such as heart rate, respiratory rate, blood pressure, body weight, and body temperature, along with measures of physical activity are essential metrics in monitoring the condition of HF patients, and whether they are self-managing appropriately to avoid acute decompensation⁶. For HF patients these are typically assessed through visits to a physician's office or heart function clinic. Indeed, HF disease management programs have been shown to be effective in improving patient self-management, quality of life, and health outcomes, although mixed-evidence exists.

The high risk of mortality⁷, excessive costs in hospitalization⁸ and the reluctance of seniors in losing their autonomy by leaving the comfort of their homes necessitates a growing demand for technology that could aid in the care of seniors within their own homes and communities to help them manage their own cardiovascular health.

Unfortunately, many seniors are unfamiliar with the methods, frequency or actions required to self-monitor their HF, which often leads to worsened health outcomes⁹. Those seniors who do possess the requisite knowledge are given standard monitoring devices such as sphygmomanometers for blood pressure readings. Unfortunately, many users do

not have dexterity to operate the devices, may not be technically savvy, may lack the required cognitive ability, and/or fail to report the results¹⁰.

Another limitation is that current products for chronic cardiac monitoring focus on physiology and activity as separate entities. For instance, products such as chest straps measure heart rate and respiration, while accelerometers monitor activity. This leads to uni-dimensional data, which requires that the user or caregiver analyze and interpret their significance. For example, after sitting in one place for an extended period of time, a senior's heart rate may be much lower than after having performed light housework around the home. A system that integrates the two measurements on the other hand, could provide a context-aware assessment of the user's condition.

This research project aims to investigate the feasibility of a smart home system that will autonomously monitor the physiology and sedentariness of seniors with HF without any conscious intervention from the users. This novel approach is accomplished by embedding passive sensors into commonly-found objects and devices in the house, a concept that will be referred to throughout this proposal as “zero-effort technology”. This technology comprises the incorporation of sensors, oximeters, thermometers, smart tiles and video technology into strategic portions of the house to monitor vital signs such as heart rate, blood pressure, body temperature, body weight, respiratory weight and sedentariness. The data collected by these devices is then submitted via a wireless network to a home server. Data from the home server is then submitted to the servers of the research team who are able to monitor the recuperation of these seniors constitutively. Besides monitoring patients with heart failure, the system can also detect and report early signs of heart failure in patients who are at risk^{7, 11}.

This research project anticipates achieving the following objectives namely;

- Accurately assessing the needs of seniors with HF and their care providers with regard to physiology and activity monitoring
- Assess the ability of zero-effort technology to accurately measure the required parameters and reliably reflect the trends in an HF patient's physiology and sedentariness over a 4-month period of cardiac rehabilitation (CR) compared to gold standard assessments made during standard twice-weekly visits to CR.
- Assess whether the developed technology will be acceptable to seniors with HF aging-in-place independently as well as to their caregivers and healthcare providers.

The following hypothesis were made regarding the research project;

- Zero-effort technology can accurately (>90%) measure vital signs, namely heart rate, respiratory rate, blood pressure, body weight, body temperature and sedentariness when compared with gold standards such as wearable heart and respiratory rate monitors, blood pressure cuffs, scales, thermometers and motion trackers, respectively.
- The new embedded system will be sensitive to change over time, such that changes in the parameters assessed during CR are reflected in the home monitoring data.
- The system will be highly accepted (>85%) by seniors with HF, their caregivers and care-providers at CR.

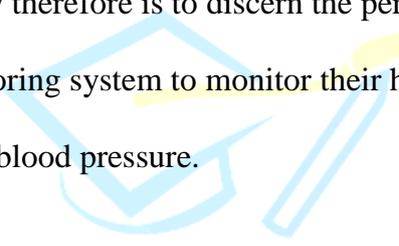
Many home care HF tele-monitoring systems have been piloted on the market so far.

CARDIAC, a chronic HF tele-monitoring system is designed to provide support to HF

patients via the agency of a conversational assistant. Research assistants provided support via telephone conversations with patients whilst implanted devices relayed information about the vital signs of patients to researchers¹². MyHeart is also a home based tele-monitoring system where patients measure their vital signs themselves or with the assistance of a care provider using provided devices every day and data is submitted via a mobile application. Based on the analysed data, patients will receive customized reminders and motivational messages to pursue a healthier lifestyle¹³. Biotronik Home Monitoring System enables daily automatic data transmission from an implanted cardiac device wirelessly to the CardioMessenger. The CardioMessenger is an external patient device that relays the recorded data via cellular networks to the Biotronik Home Monitoring Service Centre¹⁴. CardioMems, an implantable pulmonary artery pressure monitoring system touted as incredibly cost effective in the monitoring of patients with chronic heart failure¹⁵. These HF tele-monitoring systems though incredibly efficient are less desirable due to the deployment of invasive techniques, time constraints, hospitalizations in the case of failure of implantable devices and the interruptions and loss of autonomy that seniors typically experience due to the use of these devices.

Comparably, zero effort technology is based on a user-centred approach which focuses on obtaining comprehensive feedback on the physiological monitoring needs and preferences of seniors, technology that is completely non-invasive and thus does not interrupt the daily lives of patients, collected data that is contextually focused on the patient's immediate surroundings and comprehensive assessments of user acceptability of the device. The novelty of zero effort technology is that it accurately measures all the vital signs of patients without requiring the implantation of devices and it requires no conscious effort from patients to keep track of their measurements. Right in the comfort

of their homes, their vital signs are being measured by strategically placed devices that provide better temporal and spatial context to the measurements taken from patients. Moreover, zero effort technology can help prevent reactivity that may affect measurements due to patients being observed. Patients are readily examined within the context of their natural environment rather than contrived experimental settings and therefore the data gathered is much more indicative of their vital signs. Zero effort technology also aims to achieve higher user acceptability ratings compared to conventional monitoring techniques which are highly invasive, requires more time investment to maintain and are usually disruptive to the daily routine of patient. The objective of this research study therefore is to discern the perceptions of seniors with HF regarding a smart home monitoring system to monitor their heart rate, respiration rate, temperature, body weight and blood pressure.



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