Undergraduate Thesis Prospectus

Spectral Doppler Processing and Quantification in the Context of Aortic Stenosis (AS)

(technical research project in Biomedical Engineering)

The Struggle to Reduce Cardiovascular Disease in the United States through Dietary Interventions

(sociotechnical research project)

By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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General research problem

How can the incidence of cardiovascular disease be diminished?

Cardiovascular disease (CVD) remains a global leading cause of death, accounting for approximately 18 million deaths a year (WHO, 2024). The incidence of CVD, which includes conditions like heart attacks, strokes, and heart failure, is driven by a combination of lifestyle factors, genetic predispositions, and environmental influences. Its prevalence places substantial burdens on healthcare systems and families, particularly in low and middle-income communities, where rates of risk factors like hypertension, diabetes, and obesity are rising. Reducing the incidence of CVD is essential for improving overall population health, alleviating healthcare burdens, and promoting longer, healthier lives for individuals across diverse communities.

Spectral Doppler Processing and Quantification in the Context of Aortic Stenosis (AS)

How can the project team create a program to quantify low-amplitude, high-velocity (LAHV) signals from velocity-intensity histograms using data from a clinical study where echocardiography has been performed in 80 subjects with various degrees of AS (ranging from none to severe).

AS is a heart valve disease where the aortic valve narrows, restricting blood flow and leading to left ventricular thickening, enlargement, and ultimately heart failure (Mayo Clinic Staff, 2024). Diagnosed in 2-3% of adults over 65 in Western countries, AS has high healthcare costs due to necessary valve replacement surgeries, which average $59,000 (Coelho, 2022). Though typically monitored with echocardiography, AS has a 90% mortality rate within a few years after symptom onset, and no currently effective pharmacological treatment to slow its progression (Lindner, 2024). Understanding the mechanisms behind rapid versus slow disease

progression becomes increasingly important in developing emerging drug therapies. Continuous wave (CW) spectral Doppler imaging, commonly used in AS to assess pressure gradients and valve area, often reveals high-velocity, low-intensity signals that could indicate small regions of high shear stress, potentially linked to excessive Von Willebrand Factor (VWF) and accelerated disease progression (Ozawa et al., 2022).

This capstone project takes place within the Biomedical Engineering Department under the technical advisors, Dr. Jonathan Lindner and Dr. John Hossack, and in collaboration with my classmate, Lily Thomson. The research team hypothesizes that these areas of high shear may serve as a predictor of someone who has a more aggressive form of rapidly progressing AS, and of who could benefit from new therapies. The overall goal of this study is to further understand this disease state that currently has no treatment and to discover novel therapeutic targets. The project consists of developing a program to quantify LAHV signals from velocity-intensity histograms from CW Spectral Doppler images of aortic blood flow. The program will then be validated for its accuracy and predictive value by comparison to standard doppler trace algorithms and 4D Flow MRI studies done across 3D printed valves. This program could be used to predict if a patient will develop a more aggressive form of rapidly progressing AS, and deepen understanding of the disease state in a way that aids the unmet need of finding a nonsurgical treatment.

The Struggle to Reduce Cardiovascular Disease in the United States through Dietary Interventions

How are health professionals, the American Heart Association, insurers, employers, and the food industry seeking to reduce the morbidity and mortality of cardiovascular disease in the US through dietary interventions?

How are the government, media, food and pharmaceutical industries, healthcare systems, insurers, and employers seeking to reduce the morbidity and mortality of CVD in the US through dietary interventions

Heart disease has been the leading cause of death in the US since 1950, accounting for the equivalent of 1 in 5 deaths, and inflicting an economic burden of over $250 million annually from healthcare costs and productivity losses (CDC, 2023). Key risk factors for heart disease include obesity, diabetes, physical inactivity, excessive alcohol consumption, and unhealthy diets. Most of these conditions are closely linked to or directly caused by poor dietary habits.

Some popular diets that emerged and became widely recognized for their cardiovascular benefits include the Mediterranean diet, DASH diet (Dietary Approaches to Stop Hypertension), plant-based diets, low-fat diets, and low-carb diets (Scheel et al., 2019). Overall, these diets focus on lowering cholesterol, blood pressure, and inflammation (Karam et al., 2023). Clinical evidence supports that the Mediterranean and low-fat diets are best for reducing both mortality and heart attack rates in high-risk cardiovascular patients. Research also shows that occupational health programs can improve employee health and reduce healthcare costs for those at risk of CVD. In a study evaluating the impact of the DASH diet on employees with cardiac risk factors, participants experienced an average reduction of $827 in healthcare costs during the study year (Sacks et al., 2009). Additionally, a Stanford study found that implementing a workplace

wellness program significantly improved the health biometrics of participants (Einav et al., 2018).

However, dietary habits don't just pertain to individual adults and employers. In the early 2000s, growing concerns over childhood obesity led to increased advocacy for healthier school meals. A significant reform was the Healthy, Hunger-Free Kids Act (HHFKA) of 2010, which implemented more rigorous nutrition standards, including limits on calories, sodium, and unhealthy fats, while increasing whole grains, fruits, and vegetables (Kenney & Gortmaker, 2017). Recently however, some of these HHFKA standards have been relaxed due to feedback from school meal providers about cost and practicality. Today, 67% of the calories consumed by kids consist of ultra processed foods, compared to 61% in 1999 (Reynolds, 2021).

Several groups engage in mitigating CVD from the dietary approach. Health professionals advise patients on lifestyle choices that promote their heart health maintenance and recovery (Cohn, 2013). Clinicians generally comply with guidelines suggesting the best diet for their patient is one they can sustain, with a focus on quality food choices tailored to individual health goals and socioeconomic realities (Karam et al., 2023). As one cardiologist states, "In addition to the nutrition-related tips like adding more good fats and fiber to your diet, taking a simple walk, immersing yourself in nature and spending time relaxing with friends can make a big difference in your heart health," encouraging patients to adopt sustainable, heart-healthy diets and lifestyle changes (DeAngelis, 2024). However, professionals often face barriers, such as limited nutrition education in medical schools, highlighting a need for broader training and collaboration with dietitians.

The American Heart Association (AHA) aims to promote heart-healthy dietary patterns and increase public awareness about the link between diet and cardiovascular health. The AHA

also advocates for policies that promote healthier food environments, funds research, and publishes evidence-based dietary guidelines to help professionals and the public, and focuses on addressing health disparities in populations disproportionately affected by poor diet (AHA, 2023). The AHA recognizes challenges being faced in the realm of CVD prevention, stating "Assessing the value of prevention in apparently healthy patients is generally more difficult than evaluating therapy for established disease because the time horizon to the clinical manifestation of disease is generally long—many decades in the young" (Arnett et al., 2019). Accordingly, the AHA provides guidelines that highlight strategies for reducing CVD through evidence-based lifestyle interventions, risk assessments, and pharmacological treatments.

The agenda of insurance companies is driven by a balance of improving patient health outcomes and controlling healthcare costs. For example, United HealthCare incentivises healthy behaviors and promotes preventive care (2024). Anthem also emphasizes preventative care, stating, "Avoiding illness or catching problems early are key to staying healthy. Your plan covers preventive care at no cost to you when you see a doctor in your plan's network" (Anthem BCBS, 2024). Aetna addresses women's heart health, highlighting that "Heart disease is the leading cause of death among women in the U.S., and we need to change that", offering resources and coverage for heart disease screenings to promote early detection and prevention (Aetna, 2024).

Many companies have implemented initiatives to promote employee health. For instance, Google offers comprehensive wellness programs, including on-site fitness centers and healthy dining options. They note that their wellness programs are designed to "make it easy for you to take good care of yourself", so that the company can thrive as well (Google, 2024). Johnson & Johnson has been a pioneer in promoting employee health and wellness since the 1970s when its CEO launched the Live for Life® program, offering behavior modification tools and education

on nutrition and stress management (Bartz, 2018). A J&J executive stated that " our healthcare costs in the U.S. are, on average, two to three percentage points lower than the costs most major corporations deal with on an annual basis." Many employers strive to improve employee health and reduce costs associated with chronic disease, factors that are crucial for the productivity and profitability of their companies.

Food companies and trade groups influence dietary habits through product offerings, marketing, and funding nutrition research. Looking back to the 1980s, tobacco giants Philip Morris and R.J. Reynolds acquired major food companies like Kraft and Nabisco, selling "hyper-palatable" products with addictive combinations of fat, sugar, and sodium, leaving a lasting impact on consumer eating habits even after they exited the food industry in the 2000s (University of Michigan, 2023). These entities often prioritize profits, promoting foods that drive consumption but contribute to poor health outcomes. Additionally, the industry-funded health research introduces potential conflicts of interests. A 2018 analysis of peer-reviewed nutrition articles found that 13.4% disclosed food industry funding, with 55.6% of those studies reporting favorable outcomes for industry interests compared to just 9.7% of non-industry-funded research, highlighting concerns about potential bias (Sacks et al.). Nonetheless, companies like Kraft Heinz have established Global Nutrition Guidelines to enhance the nutritional quality of their products, stating "Our nutrition priorities in the coming years are to continue reducing nutrients of public health concern and gradually increase positive nutrients (fiber, minerals and vitamins) while addressing consumer preferences related to taste and texture" (Kraft Heinz, 2023).

Together, these various groups participate in a journey to reduce CVD through dietary interventions in several different yet interrelated ways. The overlaps in agendas pose an avenue

for further research. Beyond physicians, a deeper dive can be taken into medical education and the institutions that provide them. Additionally, organizations like the NIH and FDA, which play crucial roles in developing dietary guidelines and research, deserve a closer examination on their shaping of cardiovascular healthcare practices. Investigating the relationship between employers and health insurance companies may reveal additional opportunities for systemic approaches to prevention. Furthermore, the pharmaceutical industry's role in CVD management and interactions with dietary approaches could complement the exploration of the food industry's influence on nutrition and health. These interconnected dynamics present significant opportunities for advancing CVD prevention strategies.

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