Thesis Project Portfolio

Development of a Novel Fetal Heart Rate Triangulation Algorithm for Multiple Gestation Pregnancies

(Technical Report)

Case Studies of Insulin Price Regulation

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Brendan Shea

Spring, 2024

Department of Biomedical Engineering

Table of Contents

Executive Summary

Healthcare technology and policies are typically designed with the intention of addressing the needs of the largest demographic of individuals, leaving the minority populations underrepresented. For diabetic individuals, accounting for roughly 11.6% of the United States (US) population, diabetes has become the eighth leading cause of death. By increasing access to affordable insulin and other diabetic technology, through government policies and investigations, the avoidable deaths caused by insulin rationing can be reduced. Similarly, current medical technologies are designed and calibrated for use on the larger demographic groups leaving unique cases with little opportunity for monitoring and testing. Multiple gestation pregnancies account for approximately 3% of all births, with 70% of twins being born prematurely (earlier than 37 weeks of pregnancy). The standard for assessing fetal health *in utero* is by measuring the fetal heart rate. The current technology used to monitor fetal heart rates challenges the ability to produce reliable signals for multiple gestation pregnancies as the close proximity of the hearts creates situations leading to inaccurate measurements for a fetus, emphasizing the needs of minority patient populations within the healthcare system.

Fetal health *in utero* is assessed primarily through fetal heart rate monitoring and the current methods for measuring fetal heart rates are not designed for accurately detecting and separating multiple fetal heart rates. The technical report explores triangulation methods for increased accuracy in detection of fetal heart rates in multiple gestation pregnancies. The designs discussed expand on previous work conducted by a prior capstone team in which a physical model was developed. Synthetic heart rate data is generated using Matlab and then processed through the triangulation algorithm to detect the source of the fetal heart rate signal. Using the time difference of arrival between the sensors in an array and the speed of sound gave the distances between the heart and a given sensor. A physical model is developed to gather physical

data to train the triangulation algorithm. A phantom gel capable of replicating the acoustic impedances of human tissue, was molded with speakers inserted into the gel for heart replication. This project is intended to continue in future Capstone projects to further refine the physical model and triangulation algorithm.

The price of insulin in the US has increased at a rate far greater than those of any other developed country, causing insulin to become unaffordable for millions. To cap the high prescription insulin prices, federal and state governments have begun enacting policies aiming to restrict further price increases with investigations into how the price of insulin has increased so rapidly. This STS research paper discusses how a state's political leaning is influential on the policy that the state creates in relation to insulin price capping. Of the primary classification of a state during a US presidential election, conservative, liberal, and swing, two states were selected from each of the categories for policy comparison. The liberal states had policies with the greatest inclusivity providing access to capped insulin prices to the greatest number of individuals. Swing states were the pioneers in creating insulin price capping policy, however, they have been slow to make modifications to the policies to increase access or lower the price further. Lastly, the conservative states in the study offered coverage to those with state insurance, excluding the uninsured population that desperately needs access to more affordable insulin. As policies continue to be written and amended they must become more inclusive in who can gain access to the price capped insulin, as well as, begin to address the reasons behind the extremely high insulin prices.

Through both the technical report and STS paper, this document discusses the importance of designing technology that is capable of handling all patient cases and policy analysis for increased access to insulin. The design process of the technical report was educational on the

biomedical engineering design process and the complexities associated with developing a novel technology. This project was fruitful through the hardships that the team faced along the way developing our computational and communication skills although restricted because of assumptions that had to be made in the absence of human data. Additional steps can be taken to further the project as the available technology becomes more affordable and improved models of artificial human tissue become available. The STS paper was helpful in providing a holistic perspective on the state of insulin price capping policies as they are being passed on federal and state levels by all political parties. The policy analysis aided me in my comprehension of the complex interactions between the government, pharmaceutical companies, and medical community as they attempt to work towards a common goal. As time and policies continue to pass, additional work could be done to analyze the effects of the insulin policy on individuals in the long term and how it has affected those who have not been granted access to the coverage. Accessibility and affordability of healthcare is essential to protecting the lives of those from all demographic areas.