Thesis Portfolio

A One-Handed Knee Aspirator Medical Device to Aid in Arthrocentesis

(Technical Report)

Liver Transplantation: Policy and Technology

(STS Research Paper)

An Undergraduate Thesis
Presented to

The Faculty of the

School of Engineering and Applied Science

University of Virginia

In Partial Fulfillment
Of the Requirements for the Degree
Bachelor of Science in Biomedical Engineering

By Sarah Zagorin

May 5th, 2020

Technical Team Members:

Julia Donlon

Patrick Murphy

Sarah Zagorin

TABLE OF CONTENTS

There is a continual need for improvement of patient outcomes in the current healthcare system. Improved patient outcomes may be considered on large or small scales, ranging from improving a patient's experience interacting with their healthcare provider, to improving the survival rate of patients with a certain condition. This need is highlighted in the case of patients with End-stage Liver Disease, many of whom die every year waiting for a liver transplant. Which patients receive donated livers for transplant depends on where the patients live and is often associated with socioeconomic class. On a smaller scale, a procedure called arthrocentesis, which removes excess, painful fluid from the knee is uncomfortable for both the patient and physician. In my technical research, I approach this smaller scale problem by developing technology to improve arthrocentesis. My sociotechnical research addresses a larger scale issue by exploring how technological and political progress interact to improve patient outcome and address inequalities in the healthcare system. Together my research provides insight into how engineers can best help improve patient outcome within our current healthcare system.

A knee effusion is a condition in which excess synovial fluid, a natural joint lubricant, accumulates in the joint. Knee effusions may result from conditions such as osteoarthritis and are extremely painful for the patient. Currently, arthrocentesis, the only treatment and diagnostic procedure used, is performed using a needle and syringe. This process is not efficient for a single set of physician hands: one hand is used for holding the syringe in place, another for pulling back the plunger of the syringe to extract the fluid. Since the fluid buildup is not localized, the physician must also manipulate, or "milk," the knee in order to concentrate fluid to facilitate removal. Currently, physicians are unable to stabilize the needle, pull the plunger, and maneuver the fluid simultaneously. The resulting procedure is lengthy and cumbersome for both the patient and physician. The goal of my technical project was to develop a more efficient protocol by

developing a device to facilitate arthrocentesis. After many iterations, we developed a partially functional prototype through 3D modeling using CAD software and 3D printing. This gun-shaped device works using a bar-ratchet mechanism that pulls back the plunger of the syringe, allowing the physician to work the syringe using one hand, leaving their other hand free to manipulate the knee as needed. A motorized version of this device, intended to be easier for the physician to use, was modeled but never prototyped. The final fully functional version of the mechanical device as well as a full physical prototype of the motorized version and any subsequent testing was never completed due to limitations due to COVID-19.

Due to the differing supply and demand for organs, there are poor patient outcomes for those in need of a liver transplant. The organ distribution system, which is based on policy established by the Organ Procurement and Transplantation Network (OPTN), works to match organ donors and recipients based on a number of factors including medical match, medical need and location of the recipient relative to the donated organ. These geographic factors lead to inequalities in the organ distribution system, resulting in those in lower socioeconomic classes less likely to receive a lifesaving transplant. Originally, geographic factors were important because of the limited viability time of donated livers, and therefore limited time to safely transport the liver from donor to recipient. But a number of developing technologies have the potential to extend organ viability, allowing organs to be transported farther and therefore be more widely shared. These technologies have the potential to alleviate geographic based disparities. My sociotechnical research paper addresses the question “How has and will organ transplant technology interact with liver transplant policy to address inequalities in the current liver distribution system?”. My findings demonstrated a strong correlation between change in liver transplant policy the development of technologies since the 1980s. The most recent

developments in liver transplant policy, as of February 2020, show potential for additional flexibility in organ sharing as emerging technologies are adopted by clinicians.

In short, my sociotechnical research demonstrated a case successful interaction of technology and policy and told the story of the two working together to save more lives through liver transplants, improving patient outcome. This work may help engineers understand how to maximize the positive impact of their technology. Due to unforeseen limitations, a final functional prototype and testing of the knee aspiration device was not completed. If future refinements result in a device useful for clinical application, similar methods must be utilized to understand and optimize the sociotechnical network surrounding arthrocentesis.