Prospectus

Novel Force Measurement Tool for Minimally Invasive Procedures
(Technical Topic)

Technological Politics and the Implicit Bias of Personal Protective Equipment Towards Healthcare Workers on the Basis of Sex
(STS Topic)

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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Introduction

In 2018, the market size of minimally invasive (MI) surgical tools was valued at USD 20.0 billion (Grand View Research, 2019). Minimally invasive procedures are growing in popularity as they are less invasive than conventional medical procedures. These procedures often result in expedited patient recovery and reduced patient pain during the post-procedural healing process. During minimally invasive procedures, operators must carefully apply pressure while guiding surgical tools within the patient's body, because excess force may lead to patient injury. When errors of force application occur, the procedure not only puts the patient's health at risk, but also adds to the cost of the procedure due to the need for (additional) repair or correction. This problem is seen more frequently among less experienced operators, as their haptic perception is less developed (Gawande et al., 2003).

A surgeon in the Interventional Radiology department of the University of Virginia University Hospital is looking for a technical solution to address this issue of operator-induced patient injury during MI procedures, specifically aortic endograft placement and inferior vena cava (IVC) filter removal. According to the doctor in the Interventional Radiology department as well as a resident of the department, a visual feedback system for MI tools used in the aforementioned procedures would be useful for mitigating patient injury. To address this technological deficit my team will propose a numerical force measurement feedback device that can be used to help operators during MI procedures as well as to train inexperienced operators on appropriate force application.

However, only focusing on a technical solution will not be enough to fully address the posed problem. In creating this tool for surgeons, it will be necessary to consider the social and political implications of the device design on its users, so as to address the overarching issue of equal access to medical devices for healthcare workers. To explore this issue, I will be addressing the case of implicit design bias in personal protective equipment and its effect on women working within the United Kingdom's healthcare system. If we choose to focus only on the technical project and to ignore its social implications, our main project deliverable may perpetuate gender discrimination in the healthcare sector by being unequally accessible to men and women in its design. By addressing the technical and social issues of this project, our team can create a product that only functions technically but breaks the social mold of gender-based structural discrimination by providing equitable technology to healthcare professionals. A viable solution will not only address the technical issue face by operators, but also avoid gender-based discrimination by considering any implicit bias in the anthropometrics of its design. In the following sections, I will detail my team's technical research problem of developing a force feedback device for operators to avoid patient injury during MI procedures. I will then address the importance of understanding the politics of the proposed healthcare technology and its impact on the user (healthcare workers) through an analysis of the implicit bias in the design of another healthcare technology (personal protective equipment) on female healthcare workers (HCWs) in the United Kingdom, using the science, technology, and society (STS) framework of Technological Politics.

Technical Research Problem

Minimally invasive procedures are an increasingly popular method used by surgeons because they do not require a large incision; however, they leave surgeons blind to abnormal patient anatomies that could cause procedure failure. In MI surgical procedures, lack of experience can lead to improper force application which may result in patient injury. Around 53 percent of surgical errors are due to inexperience with the procedure (Gawande et al., 2003).

Although no commercial efforts have been made to address this problem, various research projects have been pursued.

One of the primary skills used by experienced operators to avoid patient injury is haptic perception of their own force application. However, this perception is easily distorted by extraneous forces (Zhou et al., 2008). Previous studies have gone into developing systems that provide external actuation to MI tools to address this issue of distorted haptic perception (Aranda-Michel et al., 2018). However, a system in which the operator loses partial control of an MI tool during a procedure could also cause errors due to limited autonomy. Other studies that approach the issue of operator error-induced injury have explored mounting sensors on operator's hands (either directly or on gloves) to obtain force measurements in endovascular navigation procedures and chest compressions in infants (Dellimore et al., 2013; Rafii-Tari et al., 2017). Proposed technology that uses force sensing gloves would not be practical in a clinical setting due to sterility regulations, inability to produce reliable data, and complexity of replicability. Force sensing systems that can be directly attached to MI surgical tools have also been developed (Fontanelli et al., 2020). However, they have only been developed and tested for MI robotic surgeries (Fontanelli et al., 2020, Sang et al., 2017). Additionally, these technologies are still in the prototyping stages and are thus not currently biocompatible (Fontanelli et al., 2020).

During procedures such as endovascular aneurysm repair, patients are at risk of iliac artery rupture due to operator error (Fontanelli et al., 2020). This is one of many consequences that may occur during MI surgeries. Without the availability of a clinically practical force sensing system, continued risk of serious complications during MI procedures persists. Further, the risk of patient injury can be costly to health care practitioners, as they will have to spend more resources on counteracting operator-induced patient injury (Rodziewicz & Hipskind, 2020). The development of a force sensing device that is applicable to a clinical setting across multiple MI tools may help reduce patient injury, as well as mitigate costs due to injury.

The goal of our technical project is to find the best design option, in regards to reproducibility, data accuracy, flexibility of use, and effectiveness of feedback to operators, for a force sensing measurement tool for MI surgical tools. Our team proposes a longitudinal force measurement device that provides operators with numerical feedback on their force application during MI procedures, specifically aortic endograft placement and IVC filter removal. Our solution focuses on providing visual feedback, to inform and potentially correct operator action, rather than limiting the operator's control during the procedure, as seen with previous external actuator systems. This device will be attachable directly to primary guidewires used in both of these procedures and will require minimal setup unlike previous innovations, such as the aforementioned wearable sensor systems (Dellimore et al., 2013; Rafii-Tari et al., 2017). Longitudinal force will be calculated by the device by measuring deflection of the guidewire and visually presenting the data to operators in real-time.

Our proposed device will be prototyped, and then analyzed by measuring linear force data produced by the device when attached to endograft implant devices and IVC filter removal devices, and tested on phantoms that mimic the composition and structure of the aorta and IVC. The effectiveness of this device will be determined by comparing recorded linear force data to accepted operator force values found in literature for the MI tools our device is tested with. This method will be deemed accurate, if data is found with an error of less than five percent compared to the data found in literature.

STS Research Problem

Personal protective equipment (PPE) has been an essential supply for frontline workers during the ongoing COVID-19 pandemic. PPE is a type of tool used by healthcare workers to protect themselves from injury or infection. During the current pandemic, it is one of the primary tools used to mitigate the spread of the coronavirus. PPE, as a technological artifact not only performs this technical work, but also performs significant political work. For example, 77 percent of National Health Service workers in the UK are women (Wielogórska & Ekwobi, 2020). However, PPE in the UK is made to anthropometrically fit men, despite being coined as unisex (Merson, 2020). Given that PPE was not made to fit men and women equally, it contributes to a power dynamic within the sector of NHS healthcare workers, where women are disproportionately disadvantaged due to inequity of PPE design. As NHS women HCWs experience greater difficulty using PPE for their work, this impedes their ability to treat patients, thus limiting their role in the workplace (Wielogórska & Ekwobi, 2020). Additionally, inequity of PPE design puts female NHS healthcare workers at a higher exposure risk to COVID-19 compared to male NHS health care workers. Current research shows that female healthcare professionals are more likely to fail face mask fit tests due to improper fitting and thus be more likely to contract COVID-19 in their workplace (Cotrin et al., 2020; Mantelakis et al., 2020). The shortage of PPE in the UK that occurred as a result of the COVID-19 pandemic has further dramatized this gender equity gap in the health care sector (Mantelakis et al., 2020).

If we continue to think that PPE only does technical work, we will miss how it functions to shape power relations between men and women in the medical workplace. The inequity of professional equipment between men and women in NHS healthcare professions coupled with the pre-existing structural issue of gender bias globally, perpetuates an environment of gender discrimination in regards to social factors in the workplace as well as health risk factors of employees.

I will draw upon the framework of Technological Politics, posed by Langdon Winner, to argue that medical personal protective equipment contributes to workplace gender-based power dynamics by marginalizing, endangering, and disempowering female healthcare workers. Technological Politics is the theory that technologies are artifacts that serve technical roles but also contain political properties, in that they are able to impact the power dynamics of particular social relationships (Winner, 1980). Technological artifacts can do this by privileging some groups, while marginalizing others, sometimes intentionally in their design and other times unintentionally by being inherently political.

I will specifically be focusing on the case of gender disparities created by PPE on healthcare workers in the National Health System (NHS) in the United Kingdom during the COVID-19 pandemic. To quantitatively and qualitatively analyze and assess the discrimination faced by health care workers on the basis of sex in this healthcare environment I will study the absenteeism levels between male and female HCWs, mask fit-test failure rates between male and female HCWs, relative number of COVID-19 cases between male and female HCWs, and PPE efficacy testimonials from female HCWs within the NHS system (Hoernke et al., 2020; "In harm's way", 2020). This study will demonstrate the role of PPE as a technological artifact that not only holds a technical function but a political function that contributes to gender discrimination in health care.

Conclusion

In this paper, the proposed technical and social solutions will be used to address the need for a force feedback system to be used in MI procedures that is accessible to healthcare workers, without discriminating by gender. The technical component of this socio-technical problem will be addressed by developing a novel numerical force feedback device. This device will measure the longitudinal force applied by operators during aortic endograft placement and IVC filter removal. This information can then be used by operators in real-time to adjust applied force to avoid patient injury during operation. This device is intended for clinical use in operating rooms, but also for use as a teaching tool for inexperienced operators.

The STS research paper will be used to analyze the gender bias created by another medical device, personal protective equipment, amongst healthcare workers and its political and social effects. Langdon Winner's STS framework of Technological Politics will be used to assess the role of PPE as a technological artifact that inherently contains implicit bias, based on anthropometrics, and thus creates a power dynamic between male and female healthcare workers. The purpose of this analysis will be to investigate the potential implication of medical device design on gender-based discrimination in the professional healthcare sector. Through addressing the technological and social implications of medical devices, our project will strive to create a tool that tackles this socio-technical problem.

Word Count: 1906

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