Wrist Fracture Reduction Simulator

Medical Simulation Training and its Setbacks

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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 my Capstone Project, my group is constructing a mechanical simulator that will be used to train physicians on how to properly reduce a distal fracture of the radius (i.e a common form of broken wrist). Current training methods for this particular problem typically involve live patients who have broken wrists, with experienced physicians giving close supervision to inexperienced trainees. This leads to some reductions being improperly performed and to the increased potential for pain in the patient. Our training model hopes to accurately simulate the feel and motion of a fracture reduction of this type, reducing the potential for malpractice and poor patient outcomes.

For my STS research, I plan to investigate medical training simulators to determine how effective they really are, and what barriers might exist to implementing them more widely. As it stands, training medical professionals using live patients is a moral and ethical gray area. On one hand, physicians have to practice on people. On the other, it is in the patients' and physicians' best interests for the physicians to have prior experience before practicing. I hope to discover why simulators, which propose improve the average outcome of first time operations, aren't being more widely produced and implemented into medical education, with an emphasis in orthopedics.

The connection between my Capstone project and my STS research should be quite clear. Both the technical project and STS research are related to medical simulators and how they can be implemented to create a more effective training environment in the medical industry. My team wants to create a medical simulator, and my research will both inform the design through a higher level evaluation and verify whether the simulator is worth designing. My technical project and research project will directly impact each other as I make progress in both.

Wrist Fracture Reduction Simulator

My Capstone project is to create, with my team, a medical training device that simulates the look and feel of a typical wrist fracture. The general form of the device will be a human arm, with some slight differences for simplicity and manufacturability purposes. A prototype CAD drawing can be seen below in Figure 1.

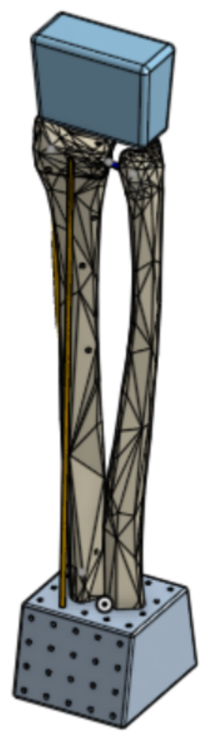

Figure 1: 3D CAD drawing of simulator prototype

Our end goal is to design a scalable, modular device that can be manufactured in-house by various medical institutions with commonly available materials. However, as of the time of writing this, we are in the ideation and prototyping phase, so we are sticking to a single, non-modular design.

The distal radius fracture, which is the most common type of wrist fracture, can be classified into many different sub-types based on the exact shape of the broken part of the bone, but the most common type is the “Colles” type. Furthermore, the groups most affected by this injury tends to be young children and aging women (Graff & Jupiter, 1994). Due to these facts, we are choosing to create our initial design to represent a Colles fracture in a fiftieth percentile female in the age range from sixty to sixty-nine.

Another aspect of our design is to keep costs low and materials available. There are a number (albeit small) of simulators out there, but they are often unaffordable while the accuracy of the simulation is also not there (Freilich, 2024). In a wrietup in the “JAAOS: Global Research and Reviews,” researchers outlined their own design for a wrist reduction simulator, which indicated it was well received by residents in training (Raeker-Jordan et al, 2021). However, this group used materials and manufacturing techniques that were not easily reproducible by common people. We are planning to use materials that can be easily 3D printed, bought from a local store, or are available through online retail for our design in order to combat this issue. The issue of simulator accuracy or more simply “feel” is a more difficult one to quantify. In order to get it right, we’ll be closely working with physicians in UVA orthopedics throughout the prototyping and refinement process of our design.

The design of the current prototype is simple and adjustable in order to make quick changes to get feedback. In order to consider our project truly successful, we need to rely on outside validation of the design’s feel, and to ensure that happens, we are using a more guided trial and error approach. Joints and fractures are hard to model accurately with cheap and readily available materials due to their complexity. There are tendons, ligaments, and muscles that all affect the forces which the fracture experiences, and it is not realistic to model each one in a mechanical simulator. Our design idea works by simplifying all the different forces and consolidating them into just a few, using elastic bands to apply them. We'll be able to adjust the direction and magnitude of these forces by pinning them to various locations on the fractured and nonfractured parts of the bone, the hand, and the solid base that these are all mounted on.

As more progress is made throughout the course of this project, we will adjust scope and the design will adjust with it. What will not change is the purpose of this design, which is to improve patient outcomes in this specific procedure.

Medical Simulation Training and its Setbacks

The STS research I wish to pursue is determining the barriers that exist to implementing medical simulation training into medical education and whether medical simulators truly affect patient outcomes, emphasizing the orthopedics sphere. Good medical training is a fundamental way to decrease the amount of pain experienced by patients and the potential for malpractice by physicians. Simulators allow physicians to gain experience with no risk, so it is important to see how we can utilize them more effectively. My research hopes to discover what barriers there are, why they exist, and if they are necessary. This goes hand in hand with improving patient outcomes, as my research will help me determine what makes a simulator succeed, and what makes one fail.

Medical simulators have been on the rise in recent years, and being able to evaluate a simulator is key to determining its effectiveness (Atesok et al, 2019) (Bradley, 2006). Through my research thus far, it has become clear that most simulators are not evaluated in a meaningful way, which makes the answer to the second part of my research question a little more difficult. According to a literature review, only 8% of commercially available simulators had even been tested for validity (Stunt et al, 2014). The same review also points out that the methodology for testing these simulators ranged from basic qualitative testing to more sound “concurrent and predictive” methodologies. Another review mentions that a large proportion of studies done on simulators do not use metrics that lead to a real understanding of their effectiveness, although the ones that do typically indicate a slight to moderate improvement in patient outcomes (Zendejas et al, 2013). These sources show me that there is more to explore in terms of simulator validation, with not enough data to truly determine how effective simulators are in general.

This brings me to the next part of my research, what barriers are in place to more widely using simulation-based medical training? The main barriers that I have been able to find so far are the aforementioned validity testing, and the human experience aspect of using simulators. First, the validity of a simulator comes in many forms, and not all are equal. As has already been outlined, certain methods of validity testing are much preferred to others, and methods that do not indicate the effect on patient outcomes do not tend to be very useful. Second, the human experience while using the simulator could also be a barrier, depending on the type of simulator and the environment in which it is used. In a University of Toronto study, it was found that the use of high fidelity simulators in anaesthesiology training induced anxiety, but this was stated to be mainly due to the training environment (Savoldelli et al, 2005).

Something that came up in my preliminary research were arguments that pushed for using simulators for more than direct procedure training. Okuda et al argues that simulators could be very useful as a competency test for experienced physicians, to ensure that they are not losing less frequently used skills. Lateef argues that in simulations which involve multiple people soft skills, like communication and teamwork, are often perceived to improve regardless of the validity of the simulator.

In a paper by a group of researchers who created a virtual reality simulation of a complicated surgical procedure, it was found that using an information centric modeling method led to a better simulation, which was then evaluated using patient outcomes to be an effective training tool (Cecil & Pirela-Cruz, 2018). I will look for examples like these, which have successful outcomes, and see what went right to help inform my conclusions about development and testing of simulators.

Conclusion

The technical project I am working on and the STS research I am doing are inextricably linked, and the success of each depends on the other. The capstone project will be hopefully improve physicians' understanding of a wrist reduction procedure, and the STS deliverable will try to determine how these simulators can be successful in medical education by identifying barriers. The medical field is constantly advancing, and the training needs to advance with it. For better simulators to be developed, we need to first understand what they are best at doing, and how it relates to improving the outcomes of patients as well as giving a more realistic and engaging training experience to physicians. When only 8% of commercially available simulators have any validation at all, we cannot truly know if what's currently out there works or not. I hope to address all of these issues and topics in my STS research.

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