OPTIMIZING PATELLAR INSTABILITY SURGICAL PLANNING

THE IMPACT OF ONLINE LEARNING ON ORTHOPEDIC MEDICAL TRAINING

A Thesis Prospectus
In STS 4500
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

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October 21, 2022

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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 does variability in surgical training impact orthopedic medical care?

It is estimated that 28.3 million orthopedic surgeries will be performed in 2022, making it a significant area of healthcare (Markets, 2019). Some of the most common procedures in this field include ACL reconstructions, knee replacements, hip replacements, and ankle repairs (Clinic, 2018). Many orthopedic surgeries involve planning processes that are heavily reliant on the surgeon's prior experiences and opinions on surgical techniques, which is distinct from other fields of medicine in which most surgical procedures have a straight-forward plan of action. In orthopedic surgery, surgeons are often moving ligaments, reshaping bones, and making fine adjustments to the patient's anatomy. This introduces the questions of what should be moved where, and how aggressive should the intervention be? Each surgeon has their own approach, resulting in different surgeons having very different answers for those questions, even when assessing the same patient.

A prominent example of this variability in surgical techniques is seen in patellar instability treatment. Patellar instability is an orthopedic disorder characterized by the patella sliding out of its natural position within the femur's trochlear groove during knee flexion and extension. Forces generated by muscles and ligaments, such as the quadriceps and medial patellofemoral ligament (MPFL), help to stabilize the patella as it tracks through the trochlear groove. An imbalance between these forces causes the patella to no longer be adequately stabilized and subluxate, which means to partially dislocate (Duchman et al., 2013). Patellar instability can be treated by physical therapy, but needs surgical intervention in more severe cases. The planning for these surgical procedures is done on a case-by-case basis and is overseen by the lead orthopedic surgeon. MRI and CT scans can help surgeons visualize the anatomy of the patient's knee, but few quantitative measurements are taken, leaving much of the planning to the surgeon's prior personal experiences and opinions of the case. Due to this being the case in many orthopedic procedures, such as patellar instability, experiences during surgical education play an immense role in the quality of care that patients receive.

In light of this, it is important to examine how interruptions to the standard educational practices impact surgeons. The most prominent interruption to this process in recent years was the Covid-19 pandemic. Most education switched to remote learning, and health care centers altered their operations in response to the pandemic. Medical schools transitioned to online classes and halted clinical rotations. Due to this, medical students across all concentrations missed important time with "standardized patients," which are learning opportunities that they encounter before being introduced to the hospital environment (AAMC). Most remaining in-person training was stunted as hospitals limited all elective surgical procedures, only performing about 69.5% of how many would be typical outside of the pandemic (Clements et al., 2021). Elective procedures encompass many orthopedic surgeries, making for a marked decrease in the number of opportunities available to medical professionals in training. It is important to

understand how these extenuating circumstances impacted the quality of orthopedic medical care during and after the pandemic. While there were fewer opportunities for in-person educational experience, the disruptions caused by the pandemic created space to reimagine how healthcare and surgical training function, creating an interesting new landscape in medicine to explore.

Optimizing Patellar Instability Surgical Planning

Can the force vector acting on the knee in cases of patellar instability be found using a patient specific model with great enough accuracy to predict surgical outcomes?

Patellar instability is an orthopedic disorder characterized by the patella sliding out of its intended position within the femur's trochlear groove during knee flexion and extension. Forces generated by muscles and ligaments, such as the quadriceps and medial patellofemoral ligament (MPFL), help to stabilize the patella as it tracks through the trochlear groove. Once there's an imbalance between these forces, the patella will no longer be adequately stabilized and will subluxate (Duchman et al., 2013). This condition is estimated to affect 50 to 77 out of 100,000 Americans while more commonly impacting young athletes (*Patellar Instability*, n.d.). Athletes are at higher risk for this injury because of repeated rapid deceleration and twisting motions which affect the net lateral force that the patella experiences (Wolfe et al., 2022). Since patellar instability is characterized by recurrent dislocations, and considering that an increase in the lateral force component can lead to further MPFL rupture, there is an emphasis on surgical treatment to address this condition (Wolfe et al., 2022). As with most surgical procedures, the operating surgeon must review the patient's case in order to determine which surgical method is most appropriate and how aggressive the treatment needs to be to address the instability. Current procedural planning methods rely almost entirely by the surgeon's experiences with previous cases. While this may work for some patients, the planning is largely guesswork and lacks sensitivity to the unique needs of each patient. These imperfect surgical plans are credited with the 25-40% chance of recurrent subluxation post-surgery (Zimmermann & Balcarek, 2020). Additionally, patients have a greater than 50% chance of recurrent dislocation after their second surgery (Zimmermann & Balcarek, 2020). With this in mind, we plan on creating a patient specific model of the knee and using this model to simulate patellar instability surgical intervention. With an effective model, surgeons could visualize the direction and magnitude of the forces acting on the patella and be able to simulate different surgical procedures. This would empower them to incorporate quantitative metrics into their planning and would eliminate the guesswork of choosing which approach is best for their patient.

Patient specific MRI data will be obtained through a partnership with local startup Springbok Analytics. MRIs will be analyzed to obtain muscle volumes and relevant bone geometries. Specifically, we will be focusing on the quadricep muscles (the rectus femoris, vastus lateralis, vastus intermedius, and vastus medialis) as they both flex and extend the knee. The vastus lateralis and vastus medialis volumes will provide a metric known as the LM ratio, which will be normalized and used to inform if there is a possible imbalance in muscle forces

acting on the knee. The bone measurements that will be taken are hip anteversion and tibial torsion, which provide insight on the alignments of the femur and tibia. This data will be imported into a software called nmsBuilder in order to build a virtual model of the patient's knee, specific to their anatomical measurements. The model will be labeled with all major bone and muscle landmarks appropriate for the region.

The nmsBuilder model is a static model, so to progress towards simulation it will be transferred to another software called OpenSim. OpenSim is known for being a platform to simulate dynamic motion and model forces on generalized muscle and bone models. We will use the data imported from nmsBuilder to customize a generalized knee model to be patient specific. Using the new model, we will estimate the torques and force vectors around the patella. Using a fourteen subject normative population database of MRIs, a healthy range for torques and net vectors will be determined. This range will allow for the identification of patients with abnormal torques acting on their knee, and will indicate in which direction the force vectors are pointing. OpenSim allows for the adjustment of components, so we will be able to approximately simulate patellar surgeries on the model in order to observe possible surgical effects on the force vectors.

Due to the inherent limitations of only having one MRI to pull data from, our simulated model will only be a rough approximation. The MRI protocols used on the scans we have access to do not allow for the visualization of ligaments and muscle fiber directions. Different imaging modalities would be required in order to gain information about how those are acting on the knee. The resources to obtain those images are outside of the scope of our project, so our focus is to obtain as much information as possible from a single MRI imaging sequence. In accordance with this, our final product will be a graphic user interface (GUI) that displays our simulated model, torque findings from the simulation, muscle volumes, LM ratio, hip anteversion, and tibial torsion. Surgeons ordinarily only have their prior experience and unsegmented MRI images as resources during the planning process. This means that they do not have knowledge of any muscle volumes or the directions in which the muscles, tendons, and ligaments are pulling on the knee. The GUI will present surgeons with those metrics alongside the OpenSim model, providing them with much more information than they would otherwise have to refer to in surgical planning.

By creating a computational model that is specific to the bone and muscle anatomy of a patient, this research will add a powerful new tool to surgical planning by quantifying possible surgical outcomes and providing surgeons with patient specific anatomical measurements. After modeling forces and torques acting on the patella, we plan to simulate MPFL reconstruction and tibial tubercle osteotomy procedures. This project will be a new predictive tool for surgical planning in orthopedic clinics and used to increase positive outcomes of patellar instability surgery.

The Impact of Online Learning on Orthopedic Medical Training

How has online medical education during the Covid-19 pandemic affected orthopedic medical care?

The Covid-19 pandemic caused education across the globe to switch from traditional in-person instruction to virtual learning methods. Medical education was no exception to this. Students reported that they missed out on key experiences in medical school such as the opportunity to practice with "standardized patients" before being thrown into clinical practice (AAMC). Elective procedures were decreased by 69.5% during the pandemic, which accounts for most of the procedures in specialties such as orthopedics (Clements et al., 2021). This means that opportunities for learning and practice beyond medical school were also impaired for surgeons in training. Overall, the pandemic was a massive disruption to the medical field's education system, especially in specialties such as orthopedics that saw a decline in cases. In the wake of this, it is important to study the impacts that this period of online learning has on medical care. More specifically, this research will seek to explore how education during the pandemic has impacted the training of orthopedic surgeons. Many orthopedic procedures, such as patellar instability, rely on the surgeon making decisions in accordance with their training, which is what makes this specialty particularly interesting to examine.

Surveys have shown that medical professionals are concerned that the pandemic had a negative effect on medical education and training. Upper level medical professionals across specialties universally responded that they were worried that staff in training would have a lower level of competence as a direct effect of the pandemic (Clements et al., 2021). In another study, medical professionals specifically in the orthopedic specialty were asked a set of questions about the pandemic's impact on their field. 78% of respondents believed that training would be moderately to highly impacted. Additionally, 59% of those polled reported that their national training body made no efforts the improve the situation imposed by Covid-19, and the reported efforts that were made were sporadic and variable in nature (Abdelazeem et al., 2022).

Surveys of medical professionals undergoing training during the pandemic were also conducted. One such study questioned orthopedic surgery residents about their perception of online learning modalities, specifically webinars, online presentations, online tests, and online patient evaluations. Webinars and online presentations were deemed moderately to highly satisfactory, while online tests and patient evaluations were deemed unsatisfactory. Accordingly, 82% of residents said they would continue webinars after the pandemic, 72% would continue online presentations, 27% would continue online tests, and 33% would continue online patient evaluations (Figueroa et al., 2020). These results are interesting because they indicate that not every aspect of the switch to online training and education was inherently bad for students. This opens up room for the consideration of continuing some of these practices, and even determining if they would be beneficial to incorporate into post-pandemic orthopedic education.

Important to consider in addition to the dissemination of medical knowledge through these modalities is the inherent loss of face-to-face contact. Studies have shown that online

learning stunts collaborative learning, student-faculty interactions, and student-student interactions. Additionally, students were less likely to engage with students they perceived to belong to different social or identity groups as them (Dumford & Miller, 2018). Considering these psychological and experiential impacts of online learning adds another dimension to the understanding of the pandemic. My research will seek to understand the extent to which medical students felt those psychological impacts and how they may have affected their learning and passion for medicine. It could be interesting to gauge the extent to which online learning dissuaded students from pursuing medicine, if at all.

In order to investigate this topic, I will use a combination of academic literature, health science data, and personal testimonies and interviews of medical professionals. There is an abundance of literature discussing the effects of the pandemic in a broad sense, but also in the more specific medical school environment. Many of these studies seem to have surveyed groups both outside of and within the orthopedic field regarding their thoughts on the effectiveness of online education and their confidence in the preparedness of the upcoming medical students. I believe that these will make for interesting commentaries, especially when looking at how senior surgeons rate their confidence in the new residents' knowledge and skills. Hospitals have exhaustive data collected on patient admissions, diagnoses, outcomes, etc. However, this may be difficult to accomplish as it seems many health systems restrict most of their data to doctors within their organization, and only make small bits readily available online. There are many testimonies of orthopedic students and surgeons available both in print and video form online. These will be great sources of anecdotal evidence. Additionally, I am in contact with a UVA orthopedic surgeon who I will likely also be able to interview. He has an office full of many types of staff involved in the orthopedic surgical process that may also make for interesting interviews. The methodology for this will need to be planned out thoroughly in order to ensure that the sampling is representative, unbiased, and performed ethically.

Conclusion

Through researching the impacts of the Covid-19 pandemic on orthopedic surgical training, I hope to better understand both the positive and negative aspects of online learning. I also hope to understand how disruptions in training change the way healthcare is administered, and if those effects are being felt in present time. Details in the delivery of healthcare can have major impacts on the individuals being treated. For that reason, I hope to enhance the tools available to surgeons in patellar instability surgical planning. I believe that the incorporation of metrics such as patient specific anatomical measurements and computational models will better inform surgeons planning patellar interventions. An effective model would empower surgeons to visualize the forces acting in the knee and would increase the rate of positive surgical outcomes. Both of these research topics tie into the greater question of how does variability in surgical training impact orthopedic medical care? The research related to the pandemic seeks to explore the effects of one distinct, large source of variation on a range of training and treatment in orthopedics. The research related to patellar instability seeks to look at one specific surgery to

assess how variations in training have resulted in high variability in surgical outcome. Each takes a different angle on the overarching question and adds an interesting perspective to it. Moving forward, research for both will be focused on tying into the other by creating links between education and outcomes.

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