Optimizing Surgical Planning for Patellar Instability Pathologies

Incentives and Possible Solutions Addressing Unnecessary Medical Care from a Clinical Perspective

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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

Patellar instability, a common condition among young athletes, is characterized by displacement of the patella, more commonly known as the knee cap, from its intended resting position. Surgical planning to resolve patellar instability is highly subjective because the optimal surgery varies depending on the unique anatomy of each patient. It is therefore not uncommon for patients to return to the operating room for a subsequent surgery. This type of care wastes precious time, energy, and money, as both surgeries could have been performed in a single operation. The objective of the technical project discussed in this study is to design a computational model that will provide surgeons with an optimal, personalized surgical plan for each patient while minimizing invasiveness.

The waste observed among patellar instability cases is not rare in current medical practices. The COVID-19 pandemic has brought the term “medical waste” to the foreground of many conversations, and the term is often associated with single-use materials such as disposable masks, syringes, and gloves. However, current medical practices in the United States encourage more than the waste of single-use materials; it promotes unnecessary medical care. Unnecessary medical care can be loosely defined as any medical action that is not useful. For the purposes of this investigation, the term will reference the excessive and unnecessary prescription and administration of medical scans, tests, and surgeries.

The financial burden put on victims of unnecessary medical care reduces their spending on basic life necessities such as food, clothing, education, and necessary healthcare. The cause of this phenomenon is multi-faceted. Clinicians argue their decisions to over administer is mainly due to psychological such as a need to use their expertise, financial gain, or patient pressure (Allen, 2018; Gawande, 2015; Stahel et al., 2017). Therefore, the purpose of the science,

technology, and society (STS) portion of this study is to analyze what factors contribute to the continuation of unnecessary medical practices as well as how medical practitioners actively engage in reducing, or even eliminating, instances of unnecessary medical care.

Technical Topic

Patellar instability is characterized by displacement of the patella from its intended resting position in the grooves present at the end of the femur and start of the tibia. Common symptoms associated with patellar instability include swelling, stiffness, trouble walking, and pain in the affected knee (Arshi et al., 2016; Ellera Gomes et al., 2004). In healthy patients, forces produced by muscles and ligaments maintain the proper patellar position, and instability results when the balance of these forces is disrupted. Patellar instability is prevalent among young athletes due to repeated elevated forces and irregular anatomical development, ultimately causing an increased net lateral force and often rupture of the MPFL (Arshi et al., 2016). For these cases, surgical options are explored to restore the forces to a normal range by correcting the patient's native anatomy (Arshi et al., 2016; Ellera Gomes et al., 2004; Thompson & Metcalfe, 2019).

Discussion with the orthopedic technical advisors of this project, Dr. David Diduch and Dr. Joe Hart, narrowed the scope of the project to explore two specific surgeries that have proved effective in the majority of cases: MPFL reconstruction and tubercle transfer. During an MPFL reconstruction surgery, muscle tissue is grafted from a patient’s hamstring and used to reattach the torn MPFL with the intention of restoring the balance of forces. If this restoring force is not strong enough, a tubercle transfer surgery is required. In this surgery, a portion of a patient’s tibia is physically cut and medially relocated. However, the “correct surgical plan” is subjectively determined; it relies on the attending surgeon’s experience and expertise. Due to this

subjectivity, patellar stabilizing surgeries have high postoperative complication rates, and it is not uncommon for patients to require a sequential corrective surgery (Arshi et al., 2016).

With this in mind, the goal of the project is to construct a computational model personalized to a patient's anatomy that quantifies the previously mentioned patellar force vectors. The vast majority of current computational, surgical, orthopedic models simulate anterior-cruciate ligament (ACL) repairs, and no published literature comprehensively models patellar stabilizing surgeries. Construction of this patellar instability model will expand on previously built software used for the dynamic biomechanical analysis of ACL injuries. Thus far, our team has been able to convert magnetic resonance (MR) images from healthy patients into a three-dimensional computational structure. After reviewing literature and discussing options with Dr. Silvia Blemker, we have identified two software packages for constructing patient-specific models: NMS Builder and OpenSim (Valente et al., 2017). We have already created a preliminary model of the patellar forces in a healthy patient.

Following the fine tuning of this model, the aim is to predict patellar net force vector changes post-MPFL reconstruction and/or tubercle transfer surgeries with the intention of guiding clinicians in surgical planning for optimal patient outcomes. To validate the use of the model, we plan on extracting clinical data from patients suffering from patellar instability. The ideal final product of this design would be a model that identifies and visually simulates the optimal surgery.

STS Topic

While patellar instability care is a prevalent example of unnecessary medical care, copious others exist. Current data indicates that there is a large volume of superfluous low-cost medical care, such cervical cancer screening for women younger than 21 years of age (Mafi et

al., 2017). Nonetheless, unnecessary high-cost procedures, such as arthroscopic partial meniscectomies, still contribute to the wasted energy, time, and finances (Sihvonen et al., 2013; Stahel et al., 2017). The current estimated amount of money wasted on excessive and/or unnecessary medical testing and treatment annually in the United States is approximately $78.2 billion (Shrank et al., 2019). However, this waste is not limited to finances; time, energy, and materials are all wasted in this process. While the topic of unnecessary medical care has been on the radar of larger hospital organizations, very little has been publicized regarding the extent of harm that the phenomenon causes. The objective of this investigation was, therefore, to use a sociotechnical systems, users, and practices framework to analyze the incentives influencing the development and continuation of unnecessary medical care, specifically focusing on oncological (cancer) diagnostics.

As stated by Hess & Sovacool, users are active in attributing "new meanings to sociotechnical systems and artifacts." The practices of these users influence the design and redesign of the sociotechnical system they are a part of. As the "use" of a system continues, the user questions, interacts with, and provides feedback so that a system may reach its optimal potential. The local needs and values of the users therefore directly alter the system itself (Hess & Sovacool, 2020; Skjølsvold & Ryghaug, 2015). Skjølsvold & Ryghaug outlined an example of this framework through a case study of smart grid pilot program in Stavanger, Norway. The city was rapidly expanding in size and population, putting pressure on the existing electricity grid. Simultaneously, the Stavanger region was about experience a large boom in senior citizens which would require increased energy costs for at-home patient care. The "region's specific demographic challenges, and the related regional healthcare sector needs" therefore molded the

development of smart grid technologies to focus on implementation of smart meters and healthcare devices on the household level (Skjølsvold & Ryghaug, 2015).

Similarly, unnecessary oncological care in the United States exemplifies the sociotechnical systems, users, and practices framework. This paper identifies the sociotechnical system to be all artifacts, or components, collectively working towards an end result of oncological medical care. I investigate patients, medical devices, medical practitioners, hospital administration, legal medical policies, and government groups overseeing medical legislation as the preliminary stakeholders. Specifically, cancer-related medical professionals (oncologists, obstetricians, primary care, etc.) are the defined user while unnecessary diagnostic cancer-related tests and treatments represent the practice of interest. The following evidence explores how cultural, psychological, and policy artifacts influence excessive and unnecessary medical screening for cancer within oncological practices in the United States.

Psychological and financial artifacts incentivize unnecessary oncological care

The onset and treatment of cancer is heavily studied, yet no cure has been discovered or manufactured. It is a puzzle that medical scientists are unable to solve. What is known is that cancer has a severe negative impact on a patient's health. Early identification of cancer increases a patient's life expectancy because tumor size may be regulated, mitigating the damage. For this reason, the United States Preventative Services Task Force recommends that adults within specific age ranges are routinely screened for colorectal, cervical, and breast (females only) cancers. However, over 45% of adults older than these age ranges continue to undergo screening, doing more harm than good (Moss et al., 2020; Schoenborn et al., 2020). The remainder of this section discusses evidence indicating potential psychological and financial reasons for this over-screening.

Medical providers' attitudes contribute to over-screening for cancers. Two major factors play into a clinician's mentality with these decisions: clinical performance measures and malpractice concerns. Clinical performance measures are a method to quantify a clinician's ability to follow a set of standards and processes, a concept borrowed from quality assurance in industrial processes. The initial intention of these measures was to ensure that all patients would receive medical care that "increase the likelihood of desired health outcomes and are consistent with current professional knowledge" (McIntyre, 2001). In the context of cancer screenings, the American Society of Clinical Oncology has historically set measures that are highly dependent on cancer screening results. Little focus has been put on analyzing the net-value of screenings, factoring in the cost to the patient. Clinicians might interpret these measures as an indication that they should recommend screening in the majority of clinical situations. The interpretive flexibility of clinical performance measures has, therefore, led to deviation from the artifact's intended design. Instead, the artifact has incentivized low-value, over-screening.

Medical professionals may have their medical license revoked if they lose a medical malpractice lawsuit. Medical malpractice is the act of a medical professional deviating from the established clinical standards for a given patient condition or situation, often involving the medical professional neglecting to perform a specific scan/test or procedure. Clinicians, patients, and personal injury attorneys all orbit around these clinical standards, but each user is interpreting the standards in different ways to protect themselves, their interests, and their responsibilities. Over-screening is not yet included in these standards, so clinicians commonly over-screen to prevent a lawsuit from ever occurring.

The results of a study by Sirovich et al. provide data to support the impact of both clinical performance measures and malpractice concerns. A survey was sent to United States primary

care providers, inquiring about reasons for excessive medical care. The results from this investigation revealed that primary care physicians were more aggressive with the administration of scans, tests, and treatments because of clinical practice measures (53%) and malpractice concerns (76%) (Sirovich, 2011). While this study might be a little dated, the findings in 2018 from Kistler et al. reflect the findings from 2009 (Kistler et al., 2018). It is therefore evident that the psychological impact of clinical performance measures and malpractice concerns increase over-screening in cancer diagnostic settings.

Lastly, the financial artifact contributing to over-screening in oncological diagnostics deals with patient return rates and clinician payment methods. Some regions and medical providers, such as many California medical practices, are based on a "pay by performance" framework. By increasing the rate of cancer screenings regardless of the value to a specific patient, these providers will have a higher chance of identifying a cancerous tumor. In turn, the provider will have a larger financial compensation and more public recognition. Moreover, a handful of clinicians have been honest enough to report that the frequency of cancer screenings they perform comprises a significant portion of their income (Boone et al., 2016), demonstrating that financial artifacts directly influence the practice of over-screening.

Next Steps

Reiterating the next steps for the technical project, we must first fine tune the preliminary healthy patient patellar force vector model that we have constructed between now and the end of November. MR images and surgical outcomes will then be collected from patients suffering from patellar instability that are about to undergo surgery. A new personalized model will be created for each of these patients. MPFL reconstruction and tubercle transfer surgeries will be simulated for each model, and the optimal surgical plan will be determined from these results. Lastly,

surgical outcomes will be compared to the predicted model outcomes so as to validate the design. We hope to accomplish these steps before the end of April 2022.

Future research on the STS topic will begin with analysis of differing medical fields such as cardiology and orthopedics. The methods of investigation will include extensive literature searches as well as interviews with clinicians from varying fields. The objective is to see whether the psychological and financial artifacts are universal across medical practices. If they are not universal, what is the underlying reason for this? Following this data collection, the aim is dive deeper into the influence of patient trust levels in unnecessary medical care. Detailed analysis of patient-clinician interaction suggests that geographical region may play a role in patient requests and low-value over-screening (Moss et al., 2020). I hope to finish with the aforementioned data collection and patient trust level analysis by the end of the spring semester. If time allows, my final goal is to explore tried or proposed solutions attempting to decrease unnecessary medical care by addressing the specified artifacts.

References

Allen, M. (2018, February 1). Unnecessary Medical Care Is More Common Than You Think. *ProPublica*. https://www.propublica.org/article/unnecessary-medical-care-is-more-common-than-you-think

Arshi, A., Cohen, J. R., Wang, J. C., Hame, S. L., McAllister, D. R., & Jones, K. J. (2016). Operative Management of Patellar Instability in the United States: An Evaluation of National Practice Patterns, Surgical Trends, and Complications. *Orthopaedic Journal of Sports Medicine, 4*(8), 232596711666287. https://doi.org/10.1177/2325967116662873

Boone, E., Lewis, L., & Karp, M. (2016). Discontent and Confusion: Primary Care Providers' Opinions and Understanding of Current Cervical Cancer Screening Recommendations. *Journal of Women's Health*, *25*(3), 255–262. https://doi.org/10.1089/jwh.2015.5326

Ellera Gomes, J. L., Stigler Marczyk, L. R., César de César, P., & Jungblut, C. F. (2004). Medial patellofemoral ligament reconstruction with semitendinosus autograft for chronic patellar instability: A follow-up study. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, *20*(2), 147–151. https://doi.org/10.1016/j.arthro.2003.11.006

Gawande, A. (2015, May 4). Overkill. *The New Yorker*. https://www.newyorker.com/magazine/2015/05/11/overkill-atul-gawande

Hess, D. J., & Sovacool, B. K. (2020). Sociotechnical matters: Reviewing and integrating science and technology studies with energy social science. *Energy Research & Social Science, 65*, 101462. https://doi.org/10.1016/j.erss.2020.101462

Kistler, C., Vu, M., Sutkowi-Hemstreet, A., Gizlice, Z., Harris, R., Brewer, N., Lewis, C., Dolor, R., Barclay, C., & Sheridan, S. (2018). Exploring factors that might influence primary-care provider discussion of and recommendation for prostate and colon cancer screening.

International Journal of General Medicine, *Volume 11*, 179–190. https://doi.org/10.2147/IJGM.S153887

Mafi, J. N., Russell, K., Bortz, B. A., Dachary, M., Hazel, W. A., & Fendrick, A. M. (2017). Low-Cost, High-Volume Health Services Contribute The Most To Unnecessary Health Spending. *Health Affairs*, *36*(10), 1701–1704. https://doi.org/10.1377/hlthaff.2017.0385

McIntyre, D. (2001). Overview, History, and Objectives of Performance Measurement. *HEALTH CARE FINANCING REVIEW*, *22*(3), 15.

Moss, J. L., Roy, S., Shen, C., Cooper, J. D., Lennon, R. P., Lengerich, E. J., Adelman, A., Curry, W., & Ruffin, M. T. (2020). Geographic Variation in Overscreening for Colorectal, Cervical, and Breast Cancer Among Older Adults. *JAMA Network Open*, *3*(7), e2011645. https://doi.org/10.1001/jamanetworkopen.2020.11645

Schoenborn, N. L., Massare, J., Park, R., Pollack, C. E., Choi, Y., & Boyd, C. M. (2020). Clinician Perspectives on Overscreening for Cancer in Older Adults With Limited Life Expectancy. *Journal of the American Geriatrics Society*, *68*(7), 1462–1468. https://doi.org/10.1111/jgs.16415

Shrank, W. H., Rogstad, T. L., & Parekh, N. (2019). Waste in the US Health Care System: Estimated Costs and Potential for Savings. *JAMA*, *322*(15), 1501. https://doi.org/10.1001/jama.2019.13978

Sihvonen, R., Paavola, M., Malmivaara, A., Itälä, A., Joukainen, A., Nurmi, H., Kalske, J., & Järvinen, T. L. N. (2013). Arthroscopic Partial Meniscectomy versus Sham Surgery for a Degenerative Meniscal Tear. *New England Journal of Medicine*, *369*(26), 2515–2524. https://doi.org/10.1056/NEJMoa1305189

Sirovich, B. E. (2011). Too Little? Too Much? Primary Care Physicians' Views on US Health Care: A Brief Report. *Archives of Internal Medicine*, *171*(17), 1582. https://doi.org/10.1001/archinternmed.2011.437

Skjølsvold, T. M., & Ryghaug, M. (2015). Embedding smart energy technology in built environments: A comparative study of four smart grid demonstration projects. *Indoor and Built Environment*, *24*(7), 878–890. https://doi.org/10.1177/1420326X15596210

Stahel, P. F., VanderHeiden, T. F., & Kim, F. J. (2017). Why do surgeons continue to perform unnecessary surgery? *Patient Safety in Surgery*, *11*(1), 1, s13037-016-0117–6. https://doi.org/10.1186/s13037-016-0117-6

Thompson, P., & Metcalfe, A. J. (2019). Current concepts in the surgical management of patellar instability. *The Knee*, *26*(6), 1171–1181. https://doi.org/10.1016/j.knee.2019.11.007

Valente, G., Crimi, G., Vanella, N., Schileo, E., & Taddei, F. (2017). nmsBuilder: Freeware to create subject-specific musculoskeletal models for OpenSim. *Computer Methods and Programs in Biomedicine*, *152*, 85–92. https://doi.org/10.1016/j.cmpb.2017.09.012