Elbow Joint Reduction Trainer

Disparities in Rural and Urban Healthcare

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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

A joint dislocation is an injury where a joint is forced out of normal position, which can be very painful and can temporarily deform and immobilize the joint. Joint dislocations are usually treated with closed reductions, which is a procedure to set a broken bone without cutting the skin open. The broken bone is put back in place, which allows it to grow back together in better alignment (Penn Medicine, 2022). There are many benefits to performing a closed reduction rather than an open reduction, which is an invasive surgical procedure to set the bones. These benefits include removal of tension on the skin, reduction in swelling, improvement in the chances that the limb will function normally once healed, decreased pain, increased likelihood the bone will heal more quickly and strongly, and lower risk of an infection in the bone. The possible risks to a closed reduction include injury of nerves, blood vessels, and other soft tissues near the bone, formation of blood clots, and new fractures - complications that may require surgical intervention. Eight percent of closed reductions result in complications (Ponce, Hedequist, Zurakowski, Atkinson, & Waters, 2004). Data showing the benefits of swiftly addressing dislocated joints is encouraging trained professionals to perform on-site reductions, rather than first transferring patients to urgent care or the emergency room. Prompt reduction of the injured joint has shown to increase patient comfort, joint integrity, and functional outcomes. The likelihood of a successful relocation is higher with a prompt reduction attempt, and addressing the injury on-site can limit the cost of healthcare while reducing psychological trauma for the patient (Wright, Brandon, & Reisman, 2020). Both the military and athletic communities experience a high rate of joint dislocations that require immediate reduction to stabilize the joint. Despite standards for multiple medical professionals that require joint reduction training, the first time a clinician performs a joint reduction is typically on a patient. In a survey of athletic trainers, 42.5 percent of athletic trainers denied receiving training in joint reduction techniques (Wright & Diede, 2021). This can lead to hesitancy or error in the technique, potentially resulting in long-term consequences. To address this need for timely, technically accurate joint reductions, Luna Labs USA is developing an elbow joint reduction trainer to teach medical personnel proper recognition of an elbow dislocation and the procedure necessary to reduce the joint. Designing and marketing elbow joint reduction trainers provides medical professionals the resources to practice joint reduction procedures under more realistic conditions and practice an unlimited number of times. The increased, high quality training should lead to a decrease in complication rates in closed joint reductions (LUNA Biomedical Technologies Group [LUNA], 2020).

Access to training resources is important in providing quality healthcare to patients. A common barrier to this is a lack of funding to afford these essential resources, which can commonly be seen in rural medical centers (Akinleye, McNutt, Lazariu, & McLaughlin, 2019). Because urban areas receive more public funding and private investment, there exists a disparity between rural and urban healthcare that impacts the lives of those rural and urban residents. This causes conditions in the respective populations that further encourage public funding and private investment to continue to go to urban areas and neglect rural areas (Rural Health Information Hub [RHIH], 2018). In the same vein, expensive resources are another side of the barrier of

underfunded medical centers (Safarani, Ravaghi, Raeissi, & Maleki, 2018). Medical equipment and teaching tools are often extremely expensive due to high research and development costs, the costs of clinical studies, and market factors (Nieves, 2022). A way to ease the problem and ensure that underfunded medical centers have access to the resources they need to provide quality healthcare to patients is to ensure the resources are more affordable (Rosenthal, Rapfogel, & Johns, 2022). Creating technologies that are too expensive contributes to the disparity between rural and urban healthcare because it prevents rural medical centers from attaining access to necessary resources that urban centers do not have trouble accessing. Creating technologies that are inexpensive and affordable to underfunded medical centers increases access to those necessary resources and helps to decrease the disparity between rural and urban healthcare. The elbow joint reduction trainer is a teaching tool that is important to improve patient care, and the affordability of this resource will dictate whether it contributes to or eases the disparity between rural and urban healthcare.

Technical Dimension

There is almost no current technology related to elbow joint reduction training. While students may learn the procedure in books and by completing the motion on a non-dislocated joint, there is no method to practice on a dislocated joint, preventing students from gaining a solid understanding of the forces and exact technique involved in a closed joint reduction (M. Chung, personal communication, November 5, 2022). The only other joint reduction trainer currently on the market is the Luna Labs shoulder joint reduction trainer, which has positively transformed joint reduction (LUNA, 2020). This is significantly different from an elbow joint reduction trainer, however, the design process and certain foundations of the shoulder joint reduction trainer will be used in the development of the elbow joint reduction trainer. The Luna Labs USA elbow joint reduction trainer will be a biofidelic, table-top tool for demonstrating and practicing reduction of a posterior elbow dislocation. The trainer will be developed using collected qualitative data from interviews with orthopedic surgeons, orthopedists, and biomechanics experts to use realistic anatomy to accurately teach the reduction technique. The elbow joint reduction trainer will be designed to be biomechanically representative of human joint functionality. The team will use SolidWorks CAD design to digitally design physiologically accurate joint mechanisms using examples of previous models, data from literature, and information obtained from expert interviews. The team will then perform force simulations and finite element analysis using SolidWorks to ensure the model meets

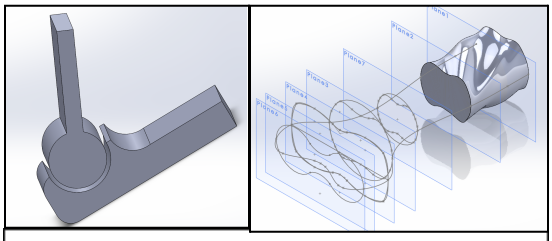

Figure 1: In-progress CAD Designs of the joint mechanism in the elbow joint reduction trainer

Figure 2: 3D-printed anatomically accurate elbow joint model

specifications determined through research (Figure 1). Rough prototypes will be 3D printed in the rapid prototyping lab using FormLabs 3D SLA and FDM printers (Figure 2). The team will determine which materials should be used for each part of the model using industry standards and durability tests on the Instron Universal Mechanical Tester. The project's goal is to simulate biomechanical joint resistances and tension elements using a spring mechanism based on previous models and data obtained from literature and expert interviews. The team will then evaluate functionality characteristics of rough prototypes to develop a polished demonstrator prototype for clinical evaluation. Initial functionality, strength, stress, and durability tests will be conducted on rough prototypes using the Instron Universal Mechanical Tester. Rough prototypes will be assessed according to literature and qualitative data gathered from experts. Demonstrator prototypes will be presented to experts experienced with reductions to solicit feedback on functionality and design. The team will then adjust the design and conduct testing as necessary until a polished elbow joint reduction trainer that is biomechanically representative of human joint functionality has been designed and created (M. Patterson, personal communication, September 15, 2022).

Once development is complete, these joint reduction trainers will be available commercially. It is typical in the healthcare industry that institutions must pay for the resources they need to train their medical students and professionals. This makes sense considering the United States' mixed market economy and capitalist society, but it fails to consider those institutions that cannot afford those resources (Sell, 2019). One of the prevalent disparities in quality of healthcare exists between rural and urban geographic areas. Rural areas face unique struggles in accessing high-quality medical care driven by innate factors like geographic size and distance, along with a market bias toward population-heavy metropolitan areas. These inherent barriers are exacerbated by the financial motives of healthcare providers themselves (Pifer, 2019). The effect of these barriers is that healthcare facilities and medical institutions in rural areas do not create enough revenue or receive enough funding to support themselves and provide high-quality care. One aspect of this is that rural medical institutions do not have the funding to secure resources to adequately train their medical students and professionals (Akinleye et al., 2019). These obstacles cause a disparity in quality healthcare between rural and urban areas, ultimately resulting in higher complication and mortality rates in rural hospitals than in urban ones (Villapiano, Iwashyna, & Davis, 2017). There is a need for funding and resources to be devoted to rural medical institutions to improve their quality of healthcare, including their training of medical professionals and students.

Human and Social Dimension

When examining the disparities in healthcare between rural and urban areas, the existing political hierarchies must be considered (Hickman, Lemley, Eisenberg, & Swan, 2022). Due to having much greater, denser populations, urban areas have larger and more stable economies, more political power, greater financial incentives for private companies to conduct business, and higher prioritization by the government to provide resources to (Kopparam, 2020). This results in

a stronger healthcare industry with better educated medical professionals as well as higher quality medical care (Pifer, 2019). Conversely, rural areas are often impoverished, economically unstable, and are often overlooked as opportunities for investment by both private and public entities (RHIH, 2018). This results in poorer quality healthcare available to those rural citizens, markedly affecting their overall health, life expectancy, and quality of life (Singh & Siahpush, 2014). There is a cycle in play here where urban areas support healthier populations, allowing the communities to flourish and create environments that are more attractive to private and public entities to focus on. It also attracts individuals to migrate to these urban areas, further increasing the population and incentive for those private and public entities to focus their efforts and resources there. On the other hand, the poor healthcare in rural areas gives rise to a less healthy and able population, further debilitating the workforce, economy, and causing individuals to migrate out of these areas and decrease the population, giving even more reason for private and public entities to choose not to focus their efforts and resources there (RHIH, 2021). As such, it is seen that disparities in healthcare are both a cause and effect of the existing political hierarchy between rural and urban areas.

Technology has influence in both healthcare and politics and often intertwines the two. The joint reduction trainer is sold by a private company to medical institutions that seek to train their medical professionals in this procedure. The basic barriers for a medical institution to obtain this technology is knowledge of the product and sufficient funds to purchase the product. Due to the political hierarchy between urban and rural areas, the private company will market more toward large, well-funded urban medical institutions rather than typically smaller, underfunded rural medical institutions. Better funded urban medical institutions have more funds to obtain joint reduction trainers, resulting in better educated medical professionals working in that area in comparison to their rural counterparts. This ultimately results in healthier urban populations compared to rural, continuing the cycle and further widening the gap in quality of care. To analyze a technology's impacts on society, a framework must be used to measure data against to come to a specific conclusion in a clear and logical manner. In his article, *Do Artifacts Have Politics?*, Winner discusses the connections a technical concept or object has to the human and social contexts around it, allowing engineers to better understand the potential impacts of a technology on society. The article examines technical arrangements as forms of order and inherently political technologies. The framework used to analyze a technology consists of four criteria or questions that can be asked about the technology being examined. First, does the technology enforce a form of order? This considers whether a technology has influence on existing political hierarchies. Secondly, is the technology democratic or authoritarian? This considers whether the nature of the technology is system-centered, immensely powerful, but inherently unstable - authoritarian - or man-centered, relatively weak, but resourceful and durable - democratic. Thirdly, what is the technology's temporal political power? This considers if the technology has the ability to influence politics and society over time and considers data regarding the technology's impact over a period of time. Lastly, what is the technology's spatial political power? This considers if the technology has the ability to influence politics and society

over a geographic area and considers data regarding the technology's impact over different geographic areas (Winner, 1980).

Research Question and Methodology

Because of the heavy influence and use of technology in healthcare, and thus in those communities, the overarching question must be considered: How does technology function in political life? In the case of the joint reduction trainer, the question becomes refined: How does the development and sale of the elbow joint reduction trainer reinforce existing disparities in quality of healthcare between urban and rural geographic areas? This question may be answered using data collection that is measured against the aforementioned criteria. The method of data collection will be to interview orthopedic specialists, clinicians, and administrators in different geographic areas varying from rural to urban. The interviews will consist of questions regarding the financial status of the medical center over time, the need for an elbow joint reduction trainer, whether the medical center is able to afford an elbow joint reduction trainer, and how this impacts the population they serve. Interviews will also be held with engineers at LUNA Labs USA to understand the nature of the technology and whether it will be priced affordably. These answers will be converted to quantitative data and have statistical analyses conducted to obtain results that can be used to answer the criteria questions of whether the elbow joint reduction trainer reinforces existing disparities in quality of healthcare between urban and rural geographic areas (Siedlecki, 2022).

Conclusion

An elbow joint reduction trainer is a single piece of technology and would ordinarily not be considered as something that could influence society. However, in analyzing it through a framework of social and human dimensions, it can be seen that the elbow joint reduction trainer does have some degree of impact - as does all technology (Winner, 1980). In considering the social and political hierarchical contexts of the existing disparities between rural and urban healthcare due to lack of funding in rural areas, one must consider whether the resources medical centers use have an impact on the existing disparity. Accessibility of those resources, specifically medical equipment and teaching tools, play a large role in dictating the quality of care a patient receives. Depending on the affordability and accessibility of the elbow joint reduction trainer, it will be found whether the technology lessens or contributes to the disparity between rural and urban healthcare. Based on current economic contexts where private healthcare companies charge exorbitant amounts for their products, it is expected that the technology will be found to contribute to the existing disparity (Lexchin, 2019). However, once this is concluded with evidence and brought to the attention of the company and the public, there is a possibility that it can be changed for the better. If the elbow joint reduction trainer is made affordable and accessible to underfunded rural hospitals, it will improve the quality of healthcare rural residents receive. This will result in a decrease in disparity between rural and urban healthcare and ultimately improve the quality of life of rural residents.

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