Undergraduate Thesis Prospectus

Understanding Pelvic Organ Prolapse: A Biofidelic Computational Model of the Pelvic Floor for Customized Medicine
(technical research project in Biomedical Engineering)

Equitable Healthcare for All: US healthcare systems and rural populations
(sociotechnical research project)

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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General Research Problem

How can equitable access to medical care in the United States be improved?

The overall well-being of populations in the United States relies on healthcare access. Julian Tudor-Hart, a British doctor, published the inverse care law in 1971. It states that the "availability of good medical care tends to vary inversely with the need for it in the population served" (Tudor Hart, 1971). How does this access to medical care extend to people of all backgrounds? Modern gentrification and urbanization only exacerbate inequities faced by low-income and minority communities in the United States (Cole & Franzosa, 2022).

Quality medical care impacts the ability to participate in society. An important consideration is that better health is associated with more frequent civic engagement (Stopka et al., 2022). Life-saving care and treatment can be equitably distributed through improved healthcare access. The presence of a constant physician and possession of medical insurance correlate to increased rates of mammography screening in women (Akinyemiju et al., 2012). Gender blindness, defined as the lack of consideration of gender in healthcare, creates barriers to quality care for women-identifying populations (Connor et al., 2020). Access to medical care, with a focus on populations who are disproportionately impacted by systemic disparities, is critical to improving the overall general health of the United States population.

Computational Modeling for Patient Specific Treatment of Pelvic Organ Prolapse

How can pessaries be redesigned to better treat symptoms of pelvic organ prolapse?

Pelvic organ prolapse (POP) is a weakening of the pelvic floor that leads to protrusion of the bladder, rectum and uterus, afflicting 50% of women over the age of 50 (Aytan et al., 2014). Patients experience painful symptoms including sexual dysfunction, pelvic pressure, vaginal

buldge, and both urinary and bowel dysfunction (Raju & Linder, 2021). The lifetime risk that a woman will have one surgery to treat prolapse is 11.1% (Olsen et al., 1997), with a reoperation rate of 29.2% (Yuk et al., 2018). Surgical techniques are risky and expensive, thus a functional non-surgical approach is required.

Pessaries are a broad range of devices that provide mechanical support to non-surgically treat POP. Pessaries are often inefficient in treating certain cases of POP, like rectal prolapse (rectocele). Fitting protocols used in clinics are often subject to physician exam, which often requires multiple follow-up visits for patients.

The first aim of this project is to create a novel computational model of pelvic organs that better represents female physiology and anatomy. Few computational models of the female pelvic floor exist, and none model posterior wall prolapse specifically. Pelvic floor musculature requires Magnetic Resonance Imaging (MRI) to most accurately visualize muscle structures. Image splicing software can recreate organ structures from MRI images in computer-aided design (CAD) software (Chanda et al., 2015). Image splicing will be used to recreate pelvic organs in Fusion 360 CAD from deidentified patient MRI data.

The computational model will guide the design of a three-dimensional physical model of the pelvic floor to test and iterate pessary prototypes. The physical model will be made of material that best matches elasticity and material properties of muscle tissue. Static stress finite element analysis (FEA) of pelvic organ tissue using the CAD model will demonstrate areas of highest vaginal wall deformation during rectocele. Results of FEA simulations will inform the design of a novel pessary device specific to rectocele.

The project advisor is Dr. William Guilford in the Department of Biomedical Engineering (BME), and will be completed in the BME Capstone course, on a team with Marissa Yee and

Mary-Jean Rowson. Successful completion of this Capstone project will consist of the computational model, physical model, and functional pessary prototype. Ideally, physicians will use a combination of these three tools: the computational model, physical model, and pessary prototype, to more efficiently treat pelvic organ prolapse, and improve pessary fits for patients with rectocele.

Equitable Healthcare for All: US Healthcare Systems and Rural Populations

How have advocates for medical equity in the U.S. worked to include rural areas?

Residents of rural areas in the United States feel the impact of limited access to high quality and affordable healthcare (Coughlin et al., 2019). Rural areas make up 66% of primary care health professional shortage areas, despite containing only 14% of the American population (Waldrop & Gee, 2022).

Nonwhite demographic groups in rural communities are disproportionately impacted by this disparity. Sub-groups within the rural minority experience specific systemic barriers to healthcare. Institutional and medical racism prevent equitable healthcare access for ethnic minorities (Grundy & Prusaczyk, 2022). LGBTQ+ members of the rural minority experience substance abuse and mental health struggles at a greater rate than their counterparts (Willging et al., 2016). Rural LGBTQ+ people face additional barriers to healthcare. Nine out of ten rural LGBTQ+ students experience harassment, both physical and verbal, and struggle to find "knowledgeable and open and affirming" healthcare providers (Hub, 2016).

Researchers in this field have proposed solutions to the rural health disparity. Grundy & Prusaczyk (2022) argue that race-intentional health policy should be considered by advocates for medical equity. Advocates of telehealth, which provides access to physician guidance via

teleconferencing, assert that it can decrease the gap between rural and urban access to healthcare. Telehealth can expand access to medical subspecialities in rural areas, as long as internet access and privacy extends to these communities (Nagata, 2020).

Community health workers (CHW), who connect healthcare and social service fields, focus specifically on a local population. CHWs can supplement the lack of rural healthcare providers (Willging et al., 2016). Waldrop and Gee (2022) argue that expanding responsibilities of trained healthcare workers, like advanced practice nurses and physician assistants, coupled with lowering barriers to entry for medical school, could improve physician shortages in rural areas.

The rural minority is an essential participant group in considering inequitable healthcare in US rural communities. Nonwhite residents of rural areas focus on an agenda of self-protection based on historical extreme medical mistrust (Kolata, 2020). A long history of eugenics in the United States underlies some of this mistrust. Minnie Lee, who was forcibly sterilized by the state of Alabama, says “it may have happened a long time ago, it still brings back memories” (Villarosa, 2022). The historical mistreatment of minorities in medicine and lack of access destroys trust in the medical field for this group. For rural communities, this mistrust is even more dangerous with little access to healthcare centers.

A sub-group in the rural minority is the LGBTQ+ community. Isolation from LGBTQ+ positive providers drives a similar agenda of self-protection based on fear of stigma surrounding their personal identities. Claire Bowels of Powell, Wyoming mentions the difficulty of finding “counseling in this area that is understanding of the LGBTQ community” (Hub, 2016). The lack of safe spaces for members of this group is another inequitable barrier to access.

Participants also include doctors working in rural areas. Ed Garner, the solo practicing doctor in Van Horn, Texas, operates “in denial,” often working 24 hour shifts at the hospital. Still, he has to tell patients that need a specialist to transfer healthcare centers, because “out here, it’s just me” (Saslow, 2019). Rural communities may have one or two physicians, but in medical deserts such as Van Horn, patients may need to travel 100+ miles for focused care. High student loan debt drives recent graduates of medical doctors to urban areas and higher pay (Waldrop & Gee, 2022), decreasing physician supply to these areas.

Medical schools are another participant group. The University of Wisconsin implemented a training program for young physicians committed to working with rural communities (WARM, n.d.). Similarly, the University of Virginia offers a rotational program for primary care School of Medicine residents in the rural community of Orange, VA. Medical schools advance agendas to expand medical reach through programs like these. The work of these institutions is essential to improving the supply of quality physicians to rural areas.

Participants also include two types of advocates for medical equity: those that center around rural health specifically, and those that focus more specifically on minority participant groups in rural areas. The National Rural Health Association (NRHA) advances agenda items focused on improving specific rural health issues, namely “Addressing Rural Declining Life Expectancy and Rural Health Equity” and “Reducing Rural Healthcare Workforce Shortages (NRHA, n.d.). The NRHA advances this agenda by providing easy-to-use guides towards grassroots advocacy.

Smaller advocacies work to support subgroups of the rural minority participant group: PFLAG National, an advocacy group in support of LGBTQ+ communities, ran a workshop on how “rural LGBTQ+ individuals are often overlooked in national conversations” (PFLAG,

2019). Pride of Rural Virginia, a subset of the Virginia Rural Health Association, works to provide a safe healthcare environment for LGBTQ+ individuals through providing training for physicians and publishing certified medical centers for free on their website (VRHA, n.d.). These advocacies address agendas of the rural minority LGBTQ+ populations through outreach, education and efforts to improve accessibility.

Voices for a Healthy Georgia (VHG), a campaign within the New Georgia Project Action Fund, works on "justice-focused remedies to systemically unjust healthcare systems," to support equitable healthcare access in the sparsely populated southwestern Georgia (VHG, n.d.). The New Georgia Project brings voting power to minority and historically disenfranchised populations in Georgia, existing at the intersection between healthcare and public policy. The VHG further highlights the important intersection between these two fields.

Branches of larger medical equity groups like the National Patient Advocate Foundation use their wider support base to "shine a light on these projects and the passion that drives them" (NPAF, n.d.). Advocates for medical equity also appear on a state-specific level. Georgians for a Healthy Future work towards an agenda supporting "policy initiatives that can strengthen our rural health system and increase access to care" (GHF, 2022).

An intersectional approach incorporating public health, public policy, and consideration of differing lived experiences of participant groups in rural populations, leads to an understanding of how healthcare advocates work to include rural communities.

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