IMPROVING PATIENT THROUGHPUT AT UVA'S EMILY COURIC CANCER CENTER

INVESTIGATING THE IMPACT OF THE AFFORDABLE CARE ACT ON CANCER OUTCOMES FOR LOW-INCOME PATIENTS

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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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THE STATE OF CANCER CARE IN THE UNITED STATES

Cancer is the second-leading cause of death in the U.S., killing more than 600,000 people in 2021 alone (Seigel et al., 2021). Cancer is a disease where cells with damaged or mutated genetic material, or DNA, replicate at an uncontrollable pace, utilizing resources needed by healthy cells. Fortunately, cancer treatments exist that can save or extend lives.

Most cancers are treated with a form of chemotherapy, which is a drug treatment that can destroy quickly-growing cells (Mayo Clinic, n.d.). Chemotherapy is delivered through a standardized “infusion” platform, where the drug is injected directly into the bloodstream by a pump that maintains a constant flow rate (United States Food and Drug Administration, n.d.). This treatment can be incredibly taxing on the body because quickly-replicating cells are not always cancerous—nausea is a common side effect of chemotherapy treatment because cells in the digestive tract replicate quickly and are thus some of the hardest-hit healthy cells (Boussios et al., 2012).

Even though the U.S. has lots of cancer treatment capacity at facilities across the country, it also contends with a significant volume of yearly cases—a projected more than 1.8 million in 2021 alone—as a factor of its population of 332 million (Moore, 2021; Siegel et al., 2021). Given the high volume of cancer patients nationwide, it is important for each cancer treatment facility to maximize the volume of patients they can treat by making their cancer centers as efficient as possible. From a holistic viewpoint, increasing the efficiency of a cancer center can benefit all stakeholders (Guzman et al., 2020). For example, increasing efficiency could mean the cancer center profits more, patient appointments take less time, and nurses burn out less frequently because they work fewer overtime hours.

At a local level, UVA's hospital system is a hub for cancer treatment in the central Virginia region. The hospital system operates five treatment facilities, including the Emily Couric Cancer Center (ECCC), which is located across the street from UVA and is responsible for around 50% of the UVA hospital's cancer treatment capacity (Fritz, 2022). The ECCC is home to 54 infusion chairs, meaning it can treat 54 patients concurrently, and frequently surpasses 110 patients on weekdays (ibid). However, despite the ECCC's high capacity to treat cancer patients, it does not currently use its chair capacity efficiently enough to meet growing demand or maximize generated revenue.

As part of my year-long technical capstone project, my team and I will analyze ECCC throughput data, conduct interviews, and observe the ECCC's infusion center to determine a strategy the ECCC can use to increase the efficiency of its operations. For my engineering thesis, I aim to research the impact of the Affordable Care Act, a landmark healthcare law enacted in 2010, on cancer outcomes for low-income patients.

PATIENT THROUGHPUT AT THE EMILY COURIC CANCER CENTER

The goal of my technical capstone is to find a strategy that can sustainably maximize the efficiency of the UVA Infusion Center within the Emily Couric Cancer Center (ECCC). We hope that, by maximizing the efficiency of the ECCC, the ECCC will be able to schedule more patients for cancer treatment appointments, allowing the center to both increase its capacity to treat cancer patients and increase its revenue.

The ECCC currently utilizes several technical tools that help it operate at its current level. One software, Epic, is the hospital's database for patient information, and is utilized by each member of the cancer center to track the status of every patient in the building (Folio3: Digital

Health, 2022). Another software, iQueue, is utilized by cancer center schedulers to intelligently schedule appointments and allowed the ECCC to increase its weekday capacity from 70-80 patients to its current level when it was implemented a few years ago (Fritz, 2022). iQueue has been shown to have a similar impact at other cancer centers, including Novant Health, a health center covering North and South Carolina (MemorialCare Innovation Fund, 2021).

Though my capstone team has not yet devised nor proposed a solution, we have conducted preliminary data analysis and defined the key variable we are attempting to optimize, the capacity of the ECCC on a standard weekday. Although the ECCC has 54 chairs, we are focusing on the 45 chairs that are in use for standard chemotherapy infusions—the center utilizes the other nine chairs for special procedures and trials, which occur sporadically (Fritz, 2022). The center is open for 10 hours per weekday, so there is a theoretical maximum of 450 chair-hours per day (ibid). Moreover, each chair is always in one of the following sequence of four states:

1. Patient in the infusion chair and infusion in process. In this case, we define the infusion process as any time the patient is actively connected to the infusion pump.
2. Patient in the infusion chair and idle. Patients are idle if they are waiting for any reason, most commonly for their medication to be mixed, or when they are being observed after an infusion. This is not necessarily wasted time.
3. Chair empty and not ready for a patient. This means that a patient has just left the chair and the cleaning staff have not yet prepared the chair for a new patient.
4. Chair empty and ready for a patient.

Our preliminary data analysis found that, on average, the ECCC spent around 290 chair-hours per day in states 1 and 2 out of its theoretical maximum of 450 chair-hours. This represents a roughly 65% utilization of the ECCC's treatment capacity, and is far below 90% utilization, the point at which analysts at the hospital have found can cause breakdowns within the facility (Fritz, 2022). We also calculated that the center staffs enough nurses to handle nearly 450 chair-hours of infusions per day, which means that the ECCC's mediocre rate represents significant levels of inefficiency within the treatment system.

In quantitative terms, our goal is to propose a roadmap for the ECCC to increase its utilization from roughly 65% to 90%. Despite this quantitative framework, the capstone is not simply a mathematical optimization problem. Any solution we develop will have to adhere to constraints like safety standards, nurse staffing, and drug availability, and will need to have a feasible implementation plan. Furthermore, we will consider long-term sustainability in our recommendation, to ensure any potential throughput increases inside the infusion center do not come at the cost of additional nurse burnout. To that end, we hope to propose a strategy to increase the ECCC's chair utilization by the end of the Fall 2022 semester, pilot aspects of the strategy in January 2023, evaluate our pilot in Spring 2023, and deliver our final recommendation in May 2023.

THE AFFORDABLE CARE ACT AND OUTCOMES FOR LOW-INCOME CANCER PATIENTS

Cancer care is a technical problem with drugs, treatments, and efficiency aplenty, but it is also a fundamentally human problem. Susan Leigh Star's (1999) paper, "The Ethnography of Infrastructure", can help us understand cancer care in the U.S. as a form of human infrastructure. Star writes that infrastructure is commonly envisioned as a "system of substrates" like pipes and roads, but that this definition is too narrow when considering larger systems like the cancer care system in the U.S. Star defines nine dimensions of infrastructure, three of which are particularly applicable to cancer care. First, infrastructure is *embedded* because it is sunk within and coordinated with other structures. Second, infrastructure is *learned as a part of membership*, because it is something to be learned about and that participants can develop a familiarity with. Finally, infrastructure is *built on an installed base*, or is built on top of infrastructure already in use (ibid).

Applying Star's framework to cancer care in the U.S., it is clear that U.S. cancer care is a form of infrastructure. Indeed, it is sunk within the healthcare and legislative systems, which are pieces of infrastructure themselves. Newly diagnosed cancer patients need to learn about their treatment plans, and become more familiar with their treatment and healthcare providers as their treatment progresses. Any new cancer drug delivered via infusion is designed to be mixed using industry-standard pharmacy methods and delivered by infusion pumps deployed in hospitals around the U.S. Interpreting cancer care as a living form of human infrastructure can help us understand how it interacts as a system with other pieces of infrastructure. In particular, I intend to use Star's framework to investigate how the cancer care system responded to a dramatic change in the healthcare system, the passage of the landmark 2010 healthcare law, the Patient Protection and Affordable Care Act (ACA).

The ACA is a law that included new rules for healthcare and expanded several programs like Medicaid, a government program to assist low-income patients with medical expenses (Rudowitz et al., 2019). In response to rising healthcare costs, the ACA was intended to improve health and make healthcare more affordable in the U.S. by expanding the availability of cheaper health insurance plans increasing patient protections and rights (Zhao et al., 2020). As a piece of infrastructure, the ACA is embedded within the healthcare system as a whole. ACA is also learned as a part of membership, since it required citizens and healthcare providers alike to become familiar with new programs and rules. Finally, it was built on an installed base, which included pre-existing government programs (e.g. Medicaid and Medicare) and the private health insurance market.

My engineering thesis will investigate the impact of the ACA on the U.S. cancer care system. Specifically, I will focus on the ACA's impact on outcomes (e.g. remission or death) for low-income cancer patients, since these were the type of patients the law was most designed to benefit (Zhao et al., 2020). As I evaluate whether the ACA was able to achieve its goal of improving health within the cancer sphere, I plan to use Star's framework to provide qualitative context for my quantitative results.

RESEARCH QUESTION AND METHODS

Research Question: How did the passage of the Patient Protection and Affordable Care Act (ACA) impact cancer outcomes for low-income cancer patients?

Previous research has indicated that the law had a significant positive impact on health insurance coverage rates for cancer patients and survivors (Moss et al., 2020; Nogueira et al., 2019). Additionally, Moss (2020) found a statistically significant disparity in cancer mortality rates between high-poverty and low-poverty counties across the U.S., with more than 20 more deaths per 100,000 patients in higher-poverty counties. However, the specific impact of the ACA on cancer outcomes for low-income patients remains an open question. Evaluating the impact of the ACA on cancer outcomes for low-income patients should help us understand whether the law had the positive impact it was intended to have. Moreover, broadening our understanding of the impact of the ACA could help inform future cancer-specific or general healthcare-related legislative action, which is frequently debated both in Congress and by the citizenry of the U.S. (Kaplan & Thomas, 2017; Kirziner et al., 2022).

Using the latest currently-available data from the National Center for Health Statistics (NCHS); the National Cancer Institute's Surveillance, Epidemiology, and End Results Program (SEER); the National Cancer Database; and the National Health Interview Survey, I plan to conduct an analysis similar to Moss (2020) to calculate cancer mortality rates in each U.S. county. Like Moss, I intend to classify counties based on their poverty rates and examine both overall cancer mortality rates and mortality rates by cancer type.

To connect my research to the ACA, I will implement a methodology similar to Nogueira et al. (2019) and divide the county mortality data into four segments that correspond to the periods before, between, and after three major ACA milestones. These milestones are the 2010 passage of the ACA when many of the law's rules originally went into effect, the 2014 expansion of Medicaid, and the 2019 reduction of the law's penalty for lacking health insurance to $0 (Davalon, 2022; Kamal et al., 2018). Throughout my regression analysis, I will take care to control for potential confounding variables, including controlling for whether the state a county is in decided to expand Medicaid within the state as allowed by the ACA (Kaiser Family Foundation, 2022). From the perspective of Star's framework, this quantitative work will help explain the extent to which U.S. citizens have learned how to navigate the new ACA markets by participating in them, and evaluate how well the ACA interfaces with pre-installed public and private healthcare systems.

Though my primary research method involves quantitative analysis, I also plan to interview members of the ECCC who have been working in the cancer center since 2010. I hope that the interviews will surface qualitative, hospital-level observations about the impact of the ACA on cancer outcomes that might not be included in the data I will be analyzing.

CONCLUSION

Cancer care in the U.S. is a complex piece of infrastructure: it is at once technical and human. My technical capstone and engineering thesis approach and dissect both aspects of cancer care. With my capstone team, I am investigating ways to increase the utilization of infusion chairs in the ECCC at UVA from its current level of 65%. If successful, our solution will help the ECCC treat higher volumes of cancer patients each day, which will give more people in central Virginia access to potentially lifesaving care. Taking a different angle, my thesis research will measure the impact of the ACA on cancer outcomes for low-income cancer patients. This research will hopefully help us understand whether the ACA effectively improved outcomes for the low-income patients that were most heavily targeted by the law, and help inform any future health-related legislative action. In May 2023, I hope that I will have produced two bodies of work that will be able to positively impact the cancer treatment ecosystem and our understanding of it.

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