Optimizing Outpatient Cancer Infusion Center Access Operations Using a Systems-Based Approach

A Technical Report submitted to the Department of Systems Engineering

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Lauren Petty

Spring, 2024

Technical Project Team Members

Simona Brkic

Jameson Knotts

Justin Ortega

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

Rupa Valdez, Department of Public Health Sciences and Systems Engineering

Optimizing Outpatient Cancer Infusion Center Access Operations Using a Systems-Based Approach

Simona A. Brkic, Jameson B. Knotts, Justin N. Ortega,
Lauren E. Petty, and Rupa S. Valdez, Ph.D.[1]

[1] University of Virginia, Charlottesville, VA 22903 USA (rsv9d@virginia.edu).

Abstract* — As demand for cancer care has increased in the US, outpatient infusion centers have been constructed to meet this rising demand. Operational inefficiencies at these centers translate into long wait times for patients, low throughput, inability to meet patient demand, and lower overall patient satisfaction. The objective of this study was to analyze the current patient flow, identify inefficiencies, and propose methods to eliminate these inefficiencies. We surveyed prior literature regarding patient processing in healthcare systems. Two observational periods were completed within a comprehensive cancer center located in the mid-Atlantic. Each period lasted approximately three hours and involved discussions with an infusion nurse, an infusion nurse scheduler, and an infusion manager. Through these approaches, we sought to gain an understanding of patient flow, clinic processes, and pain points. Additionally, data from this comprehensive cancer center's electronic health record (EHR) from July 1, 2022, to June 30, 2023, was analyzed to understand capacity and utilization. Observation and interview data were analyzed using qualitative content analysis procedures, while EHR data were analyzed using descriptive statistics. Future focus for solution exploration can hone in on the factors that influence and impact patient no-shows, as well as strategies to reduce no-show occurrences.

I. INTRODUCTION

The World Health Organization posits that more than 35 million new incidents of cancer will be present by 2050, growing by 77% from 2022 [1]. With this growth in cancer occurrences comes the inevitable rise in the patient population. A frequent treatment strategy for cancer occurrences is infusion, whereby chemotherapy medicine enters the blood via the arm [2]. Infusion centers have recently experienced an influx of need, and there is increasing desire for them to grow to meet this demand [3].

Infusion centers are also experiencing challenges in terms of capacity, whether it be time taken to be seen by a provider or wait times within the clinic [4]. In the same vein, patients across all medical institutions are experiencing the negative effects of these obstacles on their health [5].

Various options have been considered as ways to optimize the efficiency of patient flow throughout a medical network. Some medical institutions have attempted to utilize artificial intelligence to better manage complicated capacity systems [6]. Others have tried more theoretical approaches to restructuring capacity management such as creating framework diagrams of hospital capacity optimization, with positive outcomes [7]. Studies have shown that best practices in terms of efficiency vary greatly depending on the infusion center, as protocols can be vastly different [8]. Typically, guidelines are created on a case-by-case basis according to the needs of a specific infusion center [9].

Infusion centers that attempt to implement new strategies for their patient flow frequently encounter challenges. Limitations are consistently present in terms of resources and proper allocation of those resources. Finite numbers of infusion chairs, for example, provide a barrier to improving patient flow [10]. While proper management of scheduling can help increase chair capacity during peak hours of the day, this can still be difficult in a time-sensitive environment [11].

Prior literature contains gaps concerning the specific solutions implemented in infusion center environments. Limited data has been collected about the impact of enacting pragmatic changes. We used a systems-based approach to identify areas of management requiring improvement, and subsequently suggest solutions to these limitations.

II. METHODS

A. Overview

Throughout this study, the team iteratively analyzed data and presented findings to clinic staff and administrators to hone the analysis in the right direction. Additionally, direct observations were conducted in the clinic while shadowing different employees.

Employee interviews were conducted and analyzed. During weekly meetings with comprehensive cancer center leaders, the team shared findings and discussed avenues for further exploration iteratively. The team performed analysis, presented their findings to comprehensive cancer center staff, and used the feedback to perform further analyses.

B. Analysis of Electronic Health Record Data

We obtained data from the comprehensive cancer center's infusion center from July 1, 2022, till June 30, 2023. The dataset had 41 variables and 239,000 observations. The variables described patient appointments through timestamps collected at the clinic (eg. check-in, checkout), provider information (eg. department), and scheduling information (eg. floor, day of the week). Descriptive statistical analyses were performed using the software R. Graphs were created using the software R to visualize the proportion of timestamps within a reasonable time range, not in a reasonable time range, or missing, by floor, department, and clinic. The reasonable time range was identified in collaboration with clinic managers who specified how long a visit should take based on their experience in the clinic. Next, charts were developed to visualize the busiest times for each floor. These charts included a census graph of a typical week and boxplots of the number of appointments per day, broken up between AM and PM appointments, requested by clinic managers. Data about appointments were analyzed to determine the proportion that were completed, canceled, or resulted in a no-show. The comprehensive cancer center's medical and surgical oncology floors were the study's focus. Appointment length and number of appointments were visualized using boxplots and the medians per day were used to estimate the daily utilization of each floor.

C. Direct Observations

The research team performed observations on a wide range of work roles supporting the cancer center to gain an understanding of employee workflow and overall patient flow. We completed a general tour of the center followed by a detailed one-on-one walk-through with an employee. A medical assistant, receptionist, and nurse were shadowed and asked questions regarding the comprehensive cancer center workflow.

To understand the center's workflow we asked questions related to capacity and utilization of the center, clinician and staff practices, and patient experiences. This preliminary observation lasted around three hours. We conducted a second observation where an access associate senior and a nurse were shadowed and interviewed. This observation lasted approximately two hours. Following the observations we used qualitative content analysis to identify themes and patterns within the qualitative data.

D. Staff Interviews

The team conducted interviews with six cancer center staff members following direct observations. We interviewed two nurse managers, the assistant manager of initial visits, the assistant manager of follow-up visits, an access supervisor, and a Patient Friendly Access supervisor of infusion. Each interview lasted approximately thirty minutes and was attended by at least two team members, with one team member leading the discussion and another taking notes. Interviews were audio recorded with the consent of participants. We asked questions to better understand the workflow of different roles. Additionally, the interviews gave the interviewee a chance to voice their opinion on issues and potential solutions within the comprehensive cancer center. After an initial round of interviews, a subset of the interviewees were shown our analyses of EHR and observational data. We asked questions to validate the findings and ascertain the avenues of analysis meriting further exploration. Examining the findings with the comprehensive cancer center staff helped to contextualize the data analysis. Our team used an inductive approach with all four student team members involved to identify themes from both the direct observations and the interviews.

E. Solution Development with Cancer Center Staff

After analyzing data from electronic health records, observations, and interviews, we met weekly with clinic staff administrators to collaboratively discuss solutions for problems identified. These meetings generally lasted 30 minutes and started with our team presenting one of the identified problems followed by one potential solution. Following our short presentation, we asked the clinic staff to give us their thoughts on our proposed solution. The purpose of this was to collaboratively develop solutions to problems within the center with the guidance and knowledge of clinic staff.

III. RESULTS

A. Analysis of Electronic Health Record Data

Figure 1 quantifies the validity and completeness of the provided data. According to the data, 98% of the visits recorded timestamps for roomed and visit end. 62% of all visits had a visit length within the reasonable two-hour window, indicating that 38% of these timestamps were inaccurately captured. Visit length was calculated as the

difference between visit end and roomed timestamps. 56% of visits captured provider timestamps which indicated when the nurse left the room and when the provider entered within the reasonable 120-minute interval. Only 1% of data captured a reasonable checkout timestamp. This data indicated a severe lack of data reporting within this comprehensive cancer center.

Figure 1. Data Reliability Floor 3

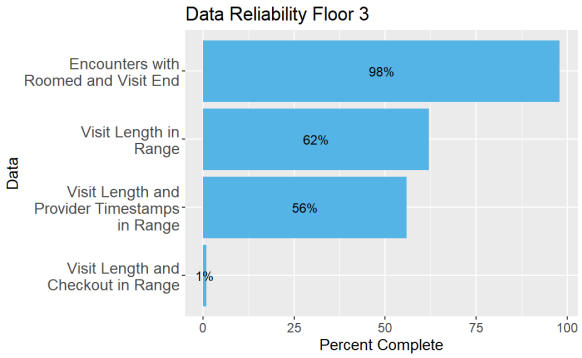


Figure 2 visualizes the number of completed appointments by day of the week. According to the analysis, Tuesdays have the most appointments per day with a median of 192. Fridays have the fewest appointments with a median of 112 appointments per day. The difference of 80 appointments between the busiest and least busy days is noteworthy and demonstrates a large variation in scheduling between days. During interviews, comprehensive cancer center staff indicated that this large variation is due to the combined influences of patient and provider scheduling preferences. The identified pattern indicates a preference for appointments on Tuesdays, Wednesdays, and Thursdays.

Figure 2. Floor 3 Number of Completed Appointments

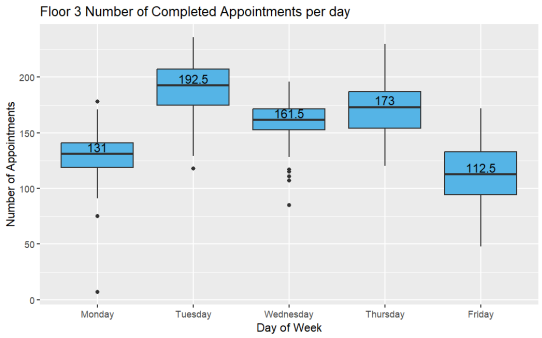


Figure 3 demonstrates the median amount of time patients spent in their rooms based on the day of the week. Time in the room was measured from the time the patient was roomed to the visit-end time stamp. The longest appointments tended to be on Wednesdays, and all appointments had a median length between 45 and 65 minutes. This chart demonstrates relatively consistent times in the room across the days of the week.

Figure 3. Median Time in Room for Floor 3

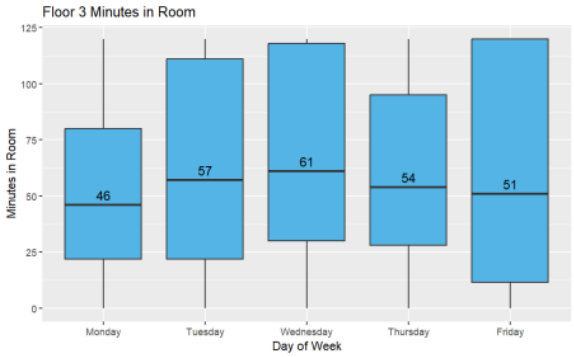


Table I displays the cancer center's estimated utilization rates by day of the week. The estimated overall utilization rate of 44% is very low. Tuesdays, Wednesdays, and Thursdays had the highest utilization rates, with Tuesdays being the highest. The days with the highest utilization rates corresponded to the days with the most completed appointments.

Table I. Utilization Estimate

Utilization Estimates	
Day of Week	% Utilization
Monday	32%
Tuesday	58%
Wednesday	52%
Thursday	50%
Friday	30%
Overall	**44%**

Figure 4 demonstrates the percentage of appointments that were completed and broken down by clinic floor. Appointments were incomplete if they resulted in a no-show, same-day cancellation, or different-day cancellation. The data indicated that around 60% of appointments were completed, 20% were canceled on a different day by the patient, and 10% of appointments were no-shows or same-day cancellations, statistics remaining relatively consistent across days of the week.

Figure 4. Appointment Completion

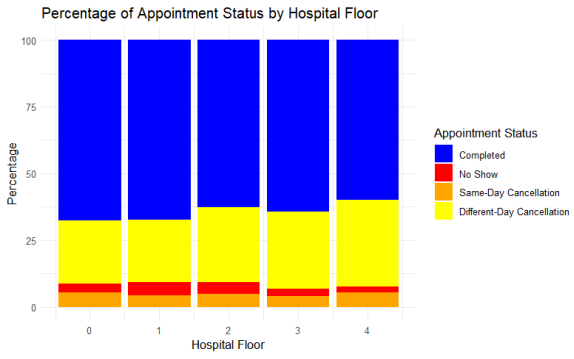
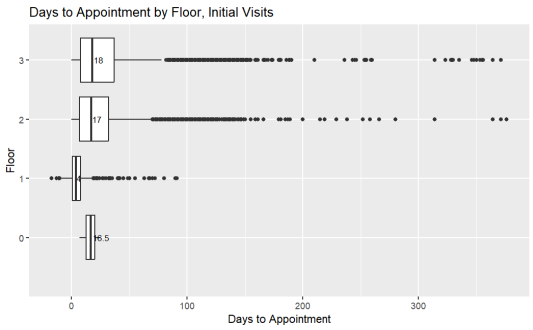


Figure 5 demonstrates how many days a patient had to wait between scheduling and an initial visit. The first floor (labeled as 1) which housed the radiology department, had a much lower median day-to-initial visit compared to all other floors. Overall, the number of days between scheduling and initial visits was deemed acceptable based on the comprehensive cancer center guidelines gleaned from interviews with schedulers and access managers in the clinic.

Figure 5. Days to Initial Visit



B. Direct Observations

Common themes discovered during observations were confusion with check-in, scheduling difficulties, and provider inconsistencies. There are east and west side check-ins in the comprehensive cancer center and many patients were unsure about their check-in site. Multiple issues were uncovered related to appointment scheduling. Varied preferences for different providers created a mismatch between supply and demand leading to operational challenges. Additionally, the occasional patient no-shows and last-minute cancellations resulted in idle providers without designated tasks.

Inconsistencies among providers' practices created confusion among the comprehensive cancer center staff and patients. Although there is varied consensus on the effectiveness of this practice, some providers engaged in the double and triple-booking of patients. Some providers preferred to call patients back as soon as a room was available while others preferred to wait until the appointment time. Different providers requested different documentation relaying patient arrivals from the medical assistants. Some providers used stickers, others preferred a handwritten note, and some requested messages written on a whiteboard to indicate arrivals.

C. Interviews

Conducting interviews with the employees revealed recurring problems within the comprehensive cancer center such as inconsistent provider practices, uneven burden for data reporting, and difficulty scheduling imaging appointments.

Many interviewees cited inconsistent provider practices as a contributing factor to delays. Scheduling practices varied significantly as some providers preferred to schedule patients for two or three appointments in one day which resulted in long wait times in between appointments. This practice was known as double or triple booking, and its impact on throughput remained unclear. One interviewee explained that this practice benefited patients who traveled from afar by allowing them to complete multiple appointments in one day. Another interviewee explained that the long wait times between appointments and the fact that double and triple-booked appointments were contingent upon the results from earlier appointments that day, led to operational challenges.

After speaking with nurses and schedulers, it became clear that physicians do not consistently enter data into the electronic health record database which may be a contributing factor to the lack of accurate timestamps. This lack of data reporting by physicians was an accepted part of the culture of this comprehensive cancer center and all those interviewed asserted that a change in this practice is highly unlikely.

The delay issues with scheduling imaging were consistently mentioned in interviews. Imaging is necessary for diagnosis and other essential functions in healthcare and refers to MRIs, PET scans, and other imaging processes. Upcoming appointments are often dependent on the results from prior imaging. If patients are unable to complete imaging, their treatment cannot progress. The comprehensive cancer center that was the focus of this research had only one imaging department for the entire healthcare system of which the clinic is a part of. As a result, it is very challenging to schedule an imaging appointment promptly making the scheduling of imaging a major bottleneck to treatment.

D. Comprehensive Staff Solution Development

Weekly meetings with the clinic staff helped clarify priorities and the limits of what was possible within the comprehensive cancer center. We presented our initial findings and potential solutions to clinic managers who provided their input on which direction would be most beneficial to them. They identified our proposed time study as a priority due to incomplete EHR data to better understand utilization and patient value-added time. The time study would be two weeks of consistent accurate timestamp collection. This would allow us to better understand data accuracy at the clinic and lead to a more complete analysis of room utilization and patient value-added time that requires accurate provider timestamps.

III. DISCUSSION

A. Summary of Key Findings

Based on a culmination of the quantitative and qualitative analyses of the comprehensive cancer center, we identified the following key issues: data reliability, access data collection efforts, room utilization, and weekly variability. Interviews provided insights into delays in patient intake, stemming from incomplete patient information. This necessitated staff to reach out to the referring clinic to gather accurate patient details, resulting in scheduling delays before the initial referral visits. Interviews also revealed inconsistencies in appointment scheduling and access data collection within the comprehensive cancer center, varying based on staff member type, and department. Low utilization rates resulted in longer patient wait times. Conducting a time study as mentioned earlier would suggest tailored solutions to improving utilization.

An additional key finding from interviews revealed several potential issues in access data and observations that have been resolved or are being addressed — such as appointment no-shows, cancellations, backlogs, reminders, and imaging scheduling. This prompted us to shift our focus and prioritize data reliability and analysis, as these overarching issues were more feasibly improvable from an external perspective. Clinic staff may have less capacity to identify the specific nuances and issues that are readily observable to outsiders. Providing insights with data analysis can more effectively pinpoint problems, empowering staff on the ground to take actionable steps toward improvement.

B. Comparison to Previous Research

Our findings aligned with previous research and expanded upon existing ideas to develop plans for future work. *Optimizing Outpatient Cancer Infusion Center Throughput Using a Systems-Based Approach* by Zavachy et al. suggested modifying preset buffer times, enhancing drug preparation, improving data reliability, automating time stamp data collection, and resolving inefficiencies between laboratory and primary care departments [6]. Our research also identified the need to improve data reliability and address inefficiencies and inconsistencies among departments. Zavachy et al. found that access data was incomplete and inaccurate due to varying data input methodologies dependent on procedure type. Our research findings corroborate these through interviews, observations, and data analyses. Moreover, Zavachy et al. found that the average utilization rate was 55% which is 7% less than our calculated 62% utilization rate [6]. Furthermore, a 2012 study found that the main barriers to patient access were long durations between initial diagnosis and treatment (lead times), inefficient capacity coordination, and ineffective patient transfer. These barriers stem from resource inefficiencies and inefficient work methods [12]. Our study developed insights into lead times and comprehensive cancer center capacity/utilization which may pose potential barriers to patient access.

C. Implications

Results from our study and previous research shed light on the comprehensive cancer center's utilization rates. However, the optimally feasible utilization rate remains unknown, given the constraints of work hours, work days, room availability, staff capacity, provider availability, and scheduled openings. Suboptimal utilization rates lead to more delays before initial visits, reduced patient turnover, and diminished patient satisfaction. As noted in *On Patient Flow in Hospitals: A Data-Based Queueing-Science Perspective by Armony et al.*, quality of care and patient satisfaction may be enhanced with better patient flow, hospital utilization, and staffing availability [13].

Additionally, inconsistencies in data both within the clinic in external referrals can lead to comprehensive cancer center inefficiencies, difficulties in contacting patients, increased time dedicated to data corrections, and prolonged time to initial visits. Such inconsistencies in data collection hinder the understanding of patient turnover and clinic efficiencies which may lead to these issues going unnoticed. Improving communication with external clinics and utilizing a patient verification process for patients to confirm information before receiving a referral may help reduce external data inconsistencies. Moreover, the implementation of a centralized system for patient intake and triage processing improved referral quality, reduced system inefficiencies, and effectively managed wait times for a large referral population as exemplified by the implementation of a Rheumatology program in 2006 [14]. Regarding access data collection within the comprehensive cancer center, standardizing data collection protocols, periodic quality assurance tests to ensure data accuracy, and conducting a time study may improve data reliability.

D. Limitations

There were several limitations to this study. The first limitation was due to data incompleteness and inaccuracy. Several observations in the dataset contained missing values for variables such as Appointment Start Time, Provider Entry Time, etc., which introduced uncertainty in calculations. Moreover, some of the timestamps were outliers, likely due to inconsistent data collection procedures and imprecise time inputs.

Another limitation of our study was the lack of observability of certain issues regarding patient access. At the start of the study, certain aspects of the comprehensive cancer center's flow were not fully understood due to their complexity. However, further research yielded new insights that challenged previous understandings of the system, providing greater clarity. Finally, in-person observations were limited to specific hours due to scheduling conflicts but supplementary access data, staff interviews, and weekly meetings with administrative staff mitigated this limitation.

E. Future Research

The analysis of our current data alone is insufficient to identify inconsistencies in procedure and methodology between different departments. Future research should prioritize conducting a structured time study to demonstrate the stronger plausibility of these data reliability issues and develop solutions to enhance access data reliability. The time study would require staff members accurately record values such as "provider enter", "provider exit", "nurse enter", and "nurse leave" times, as well as document the frequency of double or triple bookings. Identifying these subtle interactions between factors not currently demonstrated in the data may improve comprehension of the comprehensive cancer center's operations.

Additionally, pilot studies should be conducted to gauge patient satisfaction as it relates to patient throughput. Further research on the social and structural barriers to patient access such as socioeconomic status, race, geographic location, and healthcare coverage should also be conducted to determine their potential effects on patient throughput [15]. Moreover, a pilot study implementing an appointment scheduling algorithm may offer insights into enhancing patient throughput on days when underutilization is more prevalent [11].

V. CONCLUSION

We collaborated with a Central Virginia comprehensive cancer center infusion center to identify strategies for alleviating inefficiencies in patient flow. Our data suggested several areas where utilization capacity could be enhanced. Future research should expand upon these findings and involve more comprehensive cancer center staff members in the study. In addition, it would be beneficial to take our findings on utilization further by implementing targeted solutions in underutilized areas of the comprehensive cancer center infusion center.

ACKNOWLEDGEMENT

We would like to thank Joey Valdez, Jamie Ford-Lane, the interviewed staff members, and Dr. Rupa Valdez for their guidance and continued support throughout this study.

REFERENCES

[1] World Health Organization. (2024, February 1). *Global cancer burden growing, amidst mounting need for services*.

[2] Dana-Farber Cancer Institute. (2024). *What to Expect at Your Infusion Appointment*. Chemotherapy by Infusion.

[3] Mullen, K. (2019, February). *Challenges in Having an Infusion Center.* Rheumatic Disease Clinics, 45(1).

[4] D. Zavacky, A. Bustamante, H. Ratliff, & R. Valdez, "Optimizing Outpatient Cancer Infusion Center Throughput Using a Systems-Based Approach," *2023 Systems and Information Engineering Design Symposium (SIEDS)*.

[5] Gabriel, M. (2014, July). *Progress And Challenges: Implementation And Use Of Health Information Technology Among Critical-Access Hospitals*. Health Affairs, 33(7).

[6] Munavalli, J. (2020). *Real-time capacity management and patient flow optimization in hospitals using AI methods*. Artificial Intelligence and Data Mining in Healthcare.

[7] Humphreys, P. (2022). *An Overview of Hospital Capacity Planning and Optimisation*. National Library of Medicine.

[8] Sugalski, J. (2019). *National Comprehensive Cancer Network Infusion Efficiency Workgroup Study: Optimizing Patient Flow in Infusion Centers*. JCO Oncology Practice.

[9] Smith, A. (2020, August 30). *Development of a tool to allocate inpatient specialized pharmacy resources at a comprehensive cancer center.* SageJournals.

[10] Berardi, R. (2020, September 30). *Benefits and Limitations of a Multidisciplinary Approach in Cancer Patient Management*. National Library of Medicine.

[11] Rieb, W. (2015, June). Increasing patient throughput in the MGH Cancer Center Infusion Unit. DSpace@MIT.

[12] Åhlin, P. (2021). When Patients Get Stuck: a Systematic Literature Review on Throughput Barriers in hospital-wide Patient Processes. *Health Policy*, 126(2).

[13] Mor, A. (2015) *On Patient Flow in Hospitals: A Data-Based Queueing-Science Perspective*.

[14] Hazlewood, G. S. (2016). *Improving Appropriate Access to Care With Central Referral and Triage in Rheumatology*. Arthritis Care & Research.

[15] Tzenios, N. (2019). *The Determinants of Access to Healthcare: A Review of Individual, Structural, and Systemic Factors*. Journal of Humanities and Applied Science Research, *2*(1), 1–14.