OPTIMIZATION OF PATIENT FLOW AND PROCESS FOR A PRIMARY CARE CLINIC DURING THE COVID-19 PANDEMIC

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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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Optimization of Patient Flow and Process for a Primary Care Clinic During the COVID-19 Pandemic

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***Abstract*— Many patient throughput inefficiencies result from poor communication practices, inadequate understanding of optimizing healthcare systems to maximize efficiency, and long-term complications caused by the COVID-19 pandemic. The challenges precipitated by the pandemic, combined with the need to provide safe, high-quality care to patients, have further exacerbated existing patient flow and throughput issues. The overarching goal of this project is to improve the patient experience in primary care clinics and reduce the stress placed on providers, nurses, and staff. The authors implemented a two-phased approach that combined qualitative observations with quantitative data analysis, developed a robust methodology for understanding the University Physicians of Charlottesville (UPC) Clinic's processes, and produced structured insights for stakeholders. We established what components comprised a typical patient's journey through system intake through qualitative clinic observations: pre-registration, check-in, and rooming. In contrast to the qualitative observations, the quantitative analysis encompassed the complete patient experience, outscoping to include appointment durations and check-out. All quantitative analyses relied on data from the University of Virginia (UVA) Health's electronic medical record (EMR) system, Epic. In addition to the qualitative analyses, the authors utilized Cadence reports and appointment scheduling data to understand patient flow through the UPC Clinic. Primarily, the data are utilized to understand the distributions between the different patient flow milestones of registration, clinic check-in, rooming, and check-out and what factors, if any, were statistically significant. This approach enabled us to model the distribution of patient arrival times, wait times between arrival and rooming, and other relevant bottlenecks in the flow process.**

Keywords - Primary Care, COVID-19, Patient Flow, EMR

I. INTRODUCTION

The COVID-19 pandemic exacerbated many existing inefficiencies and problems for primary care clinics. The goal of this study is to help the UPC Clinic, a primary care clinic that is located in Suite 2100 of the UVA Fontaine Research Park, improve its efficiency despite the additional issues wrought by the pandemic, as well as understand and assess the impacts that the pandemic had (and continues to have) on the Clinic. We investigate factors that have impacted the Clinic's operations, improve the patient experience in the UPC Clinic, and reduce the stress placed on staff, nurses, and providers. We provide insights that are generalizable to other medical systems facing similar challenges.

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II. BACKGROUND AND RELATED WORKS

This study expands upon work conducted by Korte et al. in 2020 to 2021. We followed a phased approach similar to the one outlined in this study. That research first evaluated the current state of the UPC Clinic system, as it existed in the fall of 2020 and early 2021 (the height of the COVID-19 pandemic), and proceeded to analyze the system's pain points, implemented some recommended solutions, and tested whether those changes improved the Clinic's identified inefficiencies [1]. Whereas that work focused on implementing and testing recommendations, this study is more informational in nature and seeks to provide a comprehensive understanding of current patient flow processes.

Cohn et al. (2018) developed a methodology to understand the relationship between appointment scheduling policies, patient cancellation behaviors, and capacity utilization in outpatient specialty care clinics. This three-pronged set of factors can significantly affect whether a patient has timely access to care. Their study used data from 2014 to 2017 (pre-COVID-19), so the findings may be less applicable in the current healthcare environment, but the work can still provide valuable insights into the three-point relationship. They found that appointments were frequently canceled and rescheduled in the specialty outpatient care clinics under consideration, rescheduling was often done close to the original appointment date, and the frequency of rescheduled appointments increased for appointments made further in advance. As a result, patients were often seen later than their originally-requested date [2].

Other studies have demonstrated how the COVID-19 pandemic has created gaps in healthcare systems, specifically mental health care and primary care. Since COVID-19 limited the capacity of primary care health clinics and mental health resources, primary care health providers were forced to go online. While providers and clinics were able to transition to providing virtual care quickly, primary care clinics still need greater capacity to address increasing mental health concerns [3].

III. METHODS, DESIGN, AND APPROACH

In Phase 1 of this study, we conducted qualitative in-person observations of the Clinic to understand the processes UPC uses to check-in, room, deliver care, and check-out patients. We can subsequently identify challenges faced by nurses and providers and factors that influence Clinic operations by performing these observations. In Phase 2, we gathered and cleaned quantitative data from UVA's Epic EMR Cadence module to analyze the state of the system through the application of statistical methods. The details of the Clinic's system processes gained in Phase 1 drove the selection of valid and relevant system metrics in Phase 2.

A. Phase 1: Observations to Establish Current State

To ascertain the current state of the Clinic and understand its relevant processes, we conducted in-person observations of UPC in October 2021 through observing the main area, shared patient waiting room, and the UPC nurses' station. This study focused on patients' time spent in the UPC Clinic system alone, thus not including patient registration processes. Observational tasks involved monitoring patient flow patterns in the waiting room and gathering feedback and anecdotes from the nurses. In addition to these in-person observations, we met regularly throughout this study with one of the seven primary care doctors in the Clinic and a senior operations engineer within the UVA Health System.

1) Establishing the Patient Appointment Flow Model and Current State: During the study period, the Clinic had three nurses, one of whom was full-time and two of whom were travelers, that is, nurses who travel to different locations to fill temporary staff roles. Much of this study's understanding of the Clinic's rooming practices was gained from observations and speaking with nurses. During the pre-rooming process, which occurs before a nurse retrieves the patient from the waiting room, the nurses monitor the EMR status screen at the nurse station, which displays the names of scheduled patients and colored dots indicating the patient's status progress through the different appointment phases. The dot system is used by both nurses and providers, who change the dotting color to indicate a patient's current status. For example, after a patient has checked in with the Clinic's front desk, the dot color changes to show that they are now waiting in the waiting room. If one of the Clinic's 12 assigned rooms is available for the patient, a nurse will retrieve a patient from the waiting room and begin the rooming process.

The general process for rooming a patient involves a straightforward set of tasks. To begin, nurses confirm the patient's name and date of birth and measure their weight. During flu season, the months of October through May, nurses also ask whether a patient has received their flu shot, and if they have not and would prefer to, the nurses administer it prior to the provider entering the room. Nurses then collect the patient's vitals, review their current medications and allergies, and update their records as necessary. Additionally, the nurses record notes on any other health concerns mentioned by the patient. Sometimes, the nurses must also conduct additional patient tests or set up equipment for a provider to use, depending on the patient's health concerns. Anecdotally, we discovered from the UPC stakeholders that these rooming tasks, on average, require between 15 to 17 minutes to complete.

Following rooming protocols, the patient waits in the room until the provider enters, with the actual appointment beginning upon the provider's entry. Within UPC, the two standard appointment lengths to schedule are 20-minute and 40-minute blocks, where 20-minute appointments tend to be follow-up or sick visits, while the 40-minute appointments are generally assigned for new patient screenings, adult preventative care, and extended follow-up visits.

The UPC stakeholders expressed that, in theory, each patient's visit flow consists of the 15 to 17 minute rooming period with the nurse, which is not included within the scheduled appointment block and the appointment with the provider. For example, if a patient has a 20-minute appointment scheduled at 8:00 a.m., they are asked to arrive at least 15 minutes early so that the nurse can call them back by 7:45 a.m. Upon completing rooming tasks, the physician sees the patient starting at 8:00 a.m., with the visit ending no later than 8:20 a.m. Although the 20 and 40-minute appointment times are the designated allotment of time with the provider, physicians often actively aim to see patients for less time. Keeping appointments under the allotted time allows providers to complete administrative tasks or catch-up on their daily appointment schedules. Following their time with a provider, the patient is sent to check-out at the front desk and the Clinic visit ends. The authors' observations informed the development of the Patient Clinic Flow Model, seen in Fig. 1 below, and associated metrics of interest.

2) Initial Patient Flow Issues Identified: Throughout the observations and discussions with stakeholders in UPC, we identified three main logistical or flow issue pain points. These issues included inconsistent dotting system applications within the nursing and provider teams, confusing and fragmented informational signage in the Clinic, and a lack of physical signifiers to guide Clinic patients through the space. The dotting system problem was discovered through conversations with the nursing team about how nurses and providers inconsistently apply different dot colors. The issues with signage and overall patient navigation within the Suite were unearthed through both clinic observations and stakeholder feedback. We observed that patients often did not follow the standard procedures properly, such as by failing to complete check-out after completion of the visit and periodically asking staff for navigational help or clarification. UPC stakeholders validated these issues.

3) Addressing Initial Clinic Issues: To reduce the impact of these issues mentioned above, the authors implemented a standardized dot system guide, updated the Clinic's signage, and installed continuous color-coded floor signifiers to direct patients through the space. The guides were installed at each computer workstation to ensure that both nurses and providers had a reference available to minimize dot misclassifications within the EMR system. The research group also streamlined Clinic signage by reducing clutter and employing accessible fonts, minimalist UVA color schemes, and intuitive mental models. Finally, color-coded

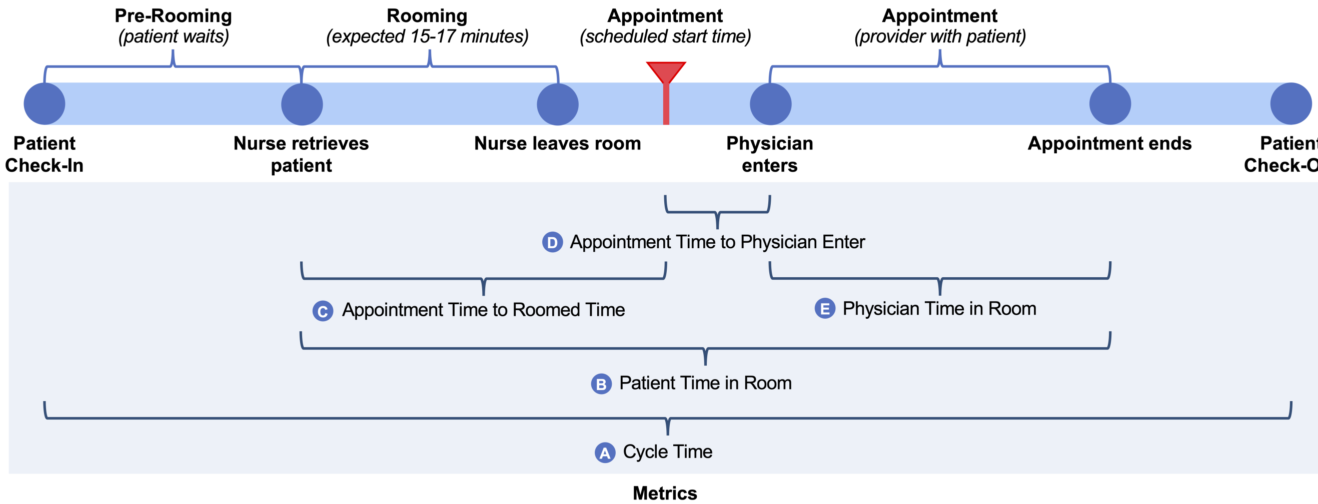

Fig. 1. Patient Clinic Flow Model

floor tape signifiers throughout common areas and hallways were installed to provide continuous navigational assistance to patients. Unfortunately, the impact of these changes was not able to be quantified as the Clinic relocated the new suite shortly after its implementation in February of 2022.

B. Phase 2: Data Gathering and Processing

Following Phase 1's observations, the authors obtained and processed data provided by UVA Health's engineering department to identify and evaluate factors affecting Clinic operations and gain insights into how the COVID-19 pandemic influenced Clinic performance. The analysis focused on patient cycle time as a metric to evaluate patients' overall experience. At a lower-level, the patient rooming experience is encompassed by submetrics, outlined in Fig. 1. Each of these metrics impacts clinic resource utilization and appointment flow timing.

1) Data Source Merging: The authors had two types of data available: raw appointment timestamp data and yearly Cadence reports that included Clinic visit metrics such as cycle time and time in the room. The data sources were combined via an inner join using the unique contact serial number (CSN) identifier. This merge enabled the researchers to create a unified dataset to complete the following analyses.

2) General Data Processing: To further process the merged data, attributes that were redundant or irrelevant to the analyses were removed. After reducing the data dimensionality, any appointment record that contained missing values in any single attribute was removed. Including observations with missing values would have prevented the calculation of the desired metrics and statistics. Due to the presence of human entry discrepancies and/or improper Cadence data recording, the research group deleted observations with invalid check-in or check-out timestamps, such as check-in and check-out timestamps outside of the Clinic's operational hours. Furthermore, the data was filtered to only include completed office visits as those appointment types were within the scope of this analysis. In addition, as there are fewer resident physicians and they provide more variable care, only appointments completed by the main primary care physicians in practice were preserved.

To facilitate analysis, new attributes were generated using the existing data. First, an attribute containing binned appointment start time was created according to the following ranges: 8 a.m. to 10 a.m., 10 a.m. to 12 p.m., 1 p.m. to 3 p.m., and 3 p.m. to 5 p.m. These categories correspond to the namings of "early morning," "late morning," "early afternoon," and "late afternoon," respectively. As no appointments were scheduled to start within the 12 p.m. to 1 p.m. lunch period, this timespan was not included. Additionally, to continuously evaluate the data from 2019 to 2021, a field for week number was added, with week 1 corresponding to the first week of 2019 and week 157 corresponding to the last week of 2021.

Finally, the data was split into two datasets by appointment length to evaluate 20-minute and 40-minute appointments separately. Within each appointment time dataset, the data was replicated and two different cleaning procedures for cycle time and the other patient rooming metrics were followed to remove outliers. The research group determined outlier values through discussion with Clinic stakeholders surrounding illogical and unreasonable values.

3) Cycle Time Outlier Filtering: For the cycle time metric, outliers were removed using the interquartile method in which any observation values outside 1.5 times the interquartile range were eliminated. Additionally, any observations with a cycle time of less than 10 minutes were removed as it is unreasonable for a patient to only spend 10 minutes within the Clinic system from check-in to check-out.

4) Patient Rooming and Appointment Data Cleaning: To prepare a dataset to analyze the patient rooming and appointment flow states, outliers were removed on granular metrics relating to cycle time. These metrics, displayed in Fig. 1, included: patient time in room, physician time in room, time between rooming and scheduled appointment start time, and time between the scheduled appointment time and when the physician enters. For patient time in room, observations with values less than 10 minutes or at least one hour over the scheduled appointment length were removed. For physician time in room, outlier removal included any records with values less than or equal to zero or one hour greater or more in excess of the scheduled appointment time. For both the time between the scheduled appointment time and when the physician enters and the time between rooming and scheduled appointment start time, records with times greater than an hour before or after the scheduled appointment time were eliminated.

5) Bootstrapping: Due to lack of data normality following outlier truncation, as noted above, the authors applied a bootstrapping method to calculate the means and respective standard deviations for the four patient rooming and appointment submetrics. The bootstrapped percentile confidence interval technique enables a non-parametric, empirical parameter estimation [4]. Although not without limitations, this method provides sufficient results for current state description in the face of non-Gaussian distributions.

C. *Provider Survey*

In addition to the observational and quantitative data, the authors also created a 20-question survey to collect a mixture of qualitative and quantitative data responses from the Clinic's primary care providers. The survey was divided into five sections: COVID-19 Vaccine and/or Booster Counseling, Pandemic-Related Fatigue and Depression Counseling, Appointments, Provider Tasks, and Provider Stress. The goal in creating and disseminating the survey was to capture anecdotal information related to the respective section topics and create a holistic image of Clinic operations by adding the provider perspective. Six out of seven providers in the UPC Clinic responded to the survey.

IV. Evaluation and Results

A. *Patient Time in System and Resource Utilization*

1) Yearly Trends: The research group evaluated general trends in cycle time for 2019 through 2021 on a weekly basis. Data was aggregated by week number to determine the median cycle time for each week. The median was used to combat outliers and the right-skewed nature of the data. Fig. 2 displays the weekly median cycle time for 40-minute appointments across all years.

There are fluctuations in 40-minute appointment median cycle times on a week-by-week basis; the median cycle time across all years is 51 minutes and the maximum median cycle time occurred during the last week of 2019, at 68 minutes.

The locally weighted smoothing lines highlight general trends for each year. The most notable and interesting finding is the trend for 2020 in which January to February experienced higher-than-median cycle times but after March and at the start of the COVID-19 pandemic, a steady decline

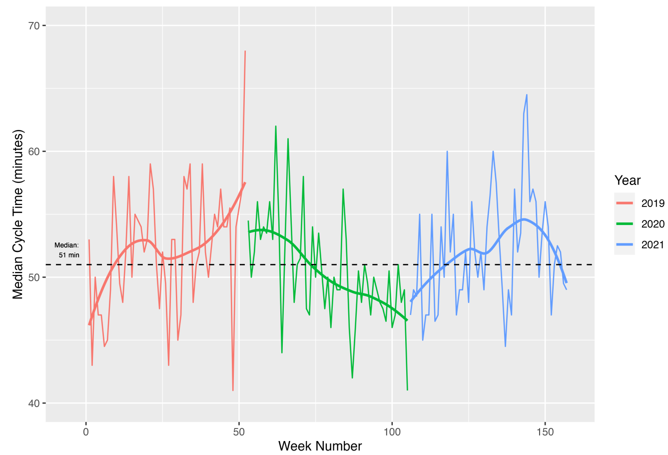

Fig. 2. Median Cycle Time of 40 Minute Appointments vs. Week Number

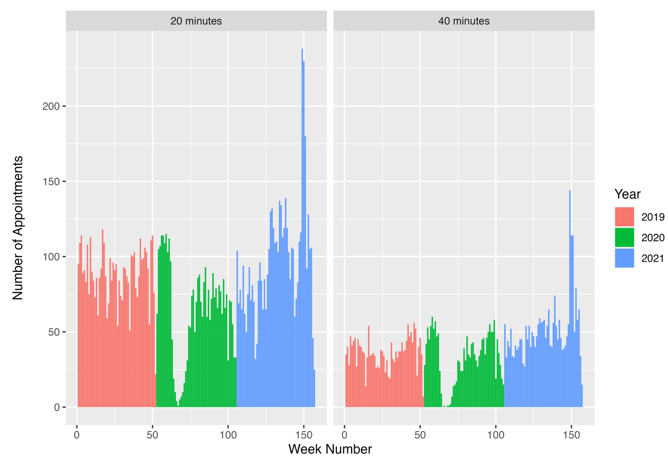

Fig. 3. Number of Appointments vs. Week Number

persisted (See Fig. 2). Correspondingly, the number of appointments starkly dropped and then quickly resumed and primarily increased in the following months (See Fig. 3). For 40-minute appointments, median cycle times by year were statistically different ($p < 0.000$) with a lower median of 50 minutes in 2020 as opposed to 52 minutes in both 2019 and 2021. For 20-minutes appointments, year was not a statistically significant factor in median appointment cycle time ($p = 0.075$).

2) Scheduled Appointment Start Time: During the authors' discussions with providers, a narrative emerged describing a phenomenon in which actual appointments get increasingly off-schedule as the day advances.

To evaluate this experience, median cycle time across all data was plotted against scheduled appointment start time for 20-minute and 40-minute appointments. For the early morning, late morning, early afternoon, and late afternoon periods, cycle times for 20-minute appointments were significantly different ($p < 0.000$) with median values of 42, 51, 47, and 49 minutes for the periods, respectively. For 40-minute appointments, cycle time was also significantly different with medians of 50, 57, 53, and 56 minutes for the periods, respectively. From Fig. 4 below and the median values, there is a general trend of lower cycle times in the early morning that significantly increase in late morning. In the afternoon, cycle times remain at an elevated level and slightly increase from early afternoon to late afternoon.

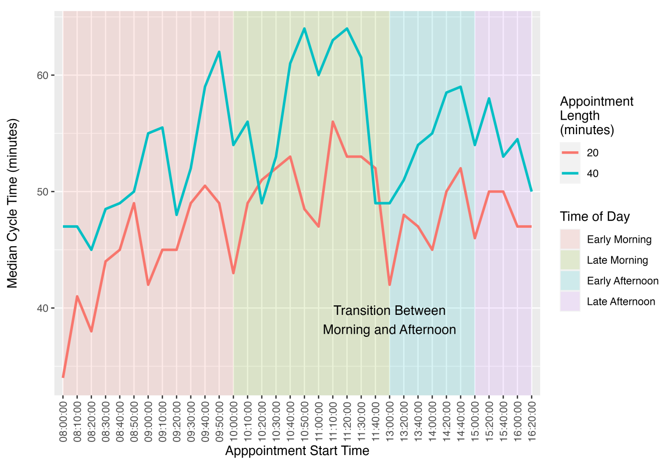

Fig. 4. Median Cycle Time vs. Scheduled Appointment Start Time

3) Provider: Cycle times differed significantly by provider for both appointment lengths across all years. For 20-minute appointments, the lowest median cycle time was 38 minutes, while the highest was 52 minutes. For 40-minute appointments, the lowest median cycle time was 42 minutes, while the highest was 59 minutes.

4) Patient Rooming Analysis: For each metric, the bootstrap sampling technique was repeated 2,750 times to approach normality in order to calculate the 95%, $\alpha = 0.05$, confidence interval estimate. The generated percentile confidence interval results are displayed in Table I.

TABLE I
RESULTS OF BOOTSTRAPPING PROCESS*

Metric	App. Length (min)	CI for μ (min)	SD (min)
B	20	(39.2, 39.6)	0.12
B	40	(45.4, 46.1)	0.19
E	20	(9.8, 10.4)	0.16
E	40	(18.7, 19.7)	0.27
C	20 & 40	(0.8, 1.2)	0.10
D	20 & 40	(27.0, 27.6)	0.15

*B stands for Patient Time in Room, E Physician Time in Room, C Appointment Time to Roomed Time, and D Appointment Time to Physician Enter.

V. Discussion and Limitations

A. Discussion

1) Year of Appointment: For 20-minute appointments, the authors' analysis indicated that the Clinic's operational changes and the general state of COVID-19 in each year did not correspond to significantly different cycle times. However, for 40-minute appointments, the year of the appointments was significant with regards to cycle time. The year 2020 had a significantly lower median cycle time than both 2019 and 2021. As this analysis cannot pinpoint exactly why cycle times differ for the 40-minute appointments across years, the authors hypothesized from anecdotal evidence that the difference may arise from the drastic decrease in the number of appointments in 2020 as the pandemic began. Although telemedicine appointments were not included in this analysis, the increase in virtual appointments may have reduced the stress on Clinic resources. This likely allowed the fewer in-person Clinic appointments that were conducted to run more smoothly.

2) Scheduled Appointment Start Time: In the authors' analysis of median cycle times for the appointment start time factor, several general patterns emerged. First, regardless of whether appointments were 20 or 40-minutes, there were steady increases in cycle time throughout the early morning, with dips occurring around mid-morning. Following these dips, the cycle times again continued to increase in late morning, with minor dips in late morning around 11 a.m., until they dropped dramatically before the lunch period (which begins at noon). In the afternoon, cycle times overall tended to remain lower than the morning cycle time peaks but appear to exhibit mirroring trends. The authors hypothesized that there are multiple potential reasons for these observed cycle time behaviors:

1) In the morning, patients that do not arrive at least 15 minutes prior to their scheduled appointments, and instead arrive closer to the scheduled appointment time, are roomed later. This immediately delays physician schedules and initiates a cycle time increase.
2) Dips in cycle time may be attributable to providers playing "catch-up" on more straightforward appointments. The authors learned through discussions with the Clinic provider contact that some appointments, such as annual preventative care exams, may be less medically less complex than other visits and therefore often take less than the allotted time to complete. This allows providers to regain time in their schedules.
3) The Clinic utilizes "patient-friendly scheduling" procedures, which may also contribute to the growth in cycle time. The central scheduling staff has little knowledge regarding the complexity of a patient's issues; they simply schedule the patient in an available slot that is convenient based on the patient's request. This blind scheduling often results in multiple, medically complex patients being scheduled back-to-back, which can delay providers and increase cycle times.

The results of the statistical and trend analyses were further validated through anecdotal data obtained from the survey answered by UPC's providers. Of the six providers who answered, five responded that their 20-minute appointments tended to run over time, and four responded that their 40-minute appointments did. Five of the six said that over half of their daily appointments tended to run over time.

3) Provider: The authors observed significant differences in the median cycle times across the Clinic's providers. Discussion with Clinic stakeholders yielded the following theories from the research group regarding why these significant differences occur:

1) The three providers with the lowest cycle times were "front-of-the-house" providers, meaning that the rooms in the Clinic that were assigned to them were directly across from the nursing station. This enabled the nurses to be more aware of when rooms for those providers became free and often resulted in the patients of those providers being roomed before others, even if other patients had been waiting longer.
2) The three providers with the lowest cycle times are the most established, in terms of length of service, in the UPC practice and therefore know their patients the best. As those providers are more keenly aware of the medical complexities of their existing patients, they may often require less time with the patient compared to a new, unfamiliar patient.
3) Finally, those three providers also have the most patients that are on privatized insurance, as opposed to Medicare or Medicaid, which means that they potentially have a demographically different set of patients than the other four providers.

Another factor that may account for some of the observed provider cycle time differences is that, during the COVID-19 pandemic, issues such as pandemic-related fatigue and increased vaccine hesitancy emerged. Both of these issues often necessitate counseling: specifically either mental health counseling or vaccine counseling. From the authors' survey results, the research group found that the percentage of appointments that providers reported having to provide pandemic-related fatigue or depression counseling ranged from 10% to 30% of appointments. Similarly, the percentage of appointments that involved vaccine counseling ranged widely from 5% to 50%.

4) Appointment Clinic Flow: After conducting data analysis regarding patient rooming processes, the researchers found the actual patient clinic flow deviates from the ideal state, as depicted in Fig. 1. Starting with the patient time in room variable for 20-minute appointments, the expected time is around 35 minutes (15 minutes rooming with the nurse, plus 20 minutes with the provider), which is slightly under the confidence interval values calculated from the data, which is (39.2, 39.6). Thus, this expectation relatively aligns with the actual data. In contrast, for 40-minute appointments, the calculated confidence interval values for the mean patient time in room metric (45.4, 46.1) were much lower than the expected value of 55 minutes (15 minutes rooming, plus 40 minutes with the provider). The driving force behind this difference became clear when the authors examined the physician time in room interval for 40-minute appointments, which is around half the expected duration (18.7, 19.7). However, in the case of 20-minute appointments, the physician time in room interval is also about half as long as the expectation (9.8, 10.4), which suggests that the patient is likely waiting for 15 minutes in the room between the nurse leaving and the physician entering.

For the appointment time to roomed time metric, the expected value is -15 minutes (the negative indicates that ideally patients are roomed 15 minutes before scheduled appointment times). However, the calculated mean is around zero minutes (0.8, 1.2). This means that, on average, patients are not roomed by nurses until right around their appointment time. This disrupts the appointment flow shown in Fig. 1.

When examining the appointment time to physician enter metric, the expected value is 0 minutes; however, the mean is over 20 minutes (27.0, 27.6). This means that, on average, the physician does not enter a patient's room until around 27 minutes after the patient's scheduled appointment time.

Based on this analysis, it appears that the realized flow of an average appointment is as follows. A patient is called from the waiting room by a nurse and roomed near their scheduled appointment time. After rooming, the patient spends 15 minutes with the nurse then spends around 15 additional minutes waiting for the physician to enter. When the physician enters, they attend to the patient for around half of the scheduled appointment length.

B. Limitations

Though the Cadence data contained valuable information, inconsistencies and inaccuracies existed which created limitations for these analyses. Due to ambiguity surrounding metric calculation in Cadence, the authors made assumptions regarding the start and endpoints of when cycle time and time in room were determined. Many missing and unreasonable values led to the exclusion of large subsets of the data. Additionally, due to a lack of normality in the data, the analysis was limited to non-parametric statistical tests.

VI. Conclusion

The framework developed in this research uniquely combined qualitative observation, direct communication with stakeholders, and quantitative analysis to produce a robust set of observations, analysis, and inferences. This process and accompanying insights are generalizable to other clinics facing similar inefficiencies.

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