A Systems Approach to Optimizing Patient Flow 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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***Abstract*—In 2020, health systems have been affected by the novel coronavirus (COVID-19) pandemic, causing an influx of COVID-19 related visits and a sharp decline in non-emergency and elective visits. To mitigate the spread of COVID-19, healthcare systems – including the University of Virginia Health System – reduced ambulatory visits and implemented various social distancing measures, resulting in a drastic change in the patient admittance process. The focus of this work is to accurately characterize the effect of COVID-19 on one of the UVA Internal Medicine, Primary Care clinics, and where possible, to refine and optimize patient flow through the appointment process while accommodating public health restrictions. To achieve these goals, the team adopted a systems approach, which involves the iterative process of problem identification, analysis, and testing recommendations.**

The first phase of the project focused primarily on establishment of the current state and problem identification. The appointment process contains six major elements: scheduling, sign-in/remote registration, check-in, rooming, check-out, and telemedicine. Through extensive discussions with the clients, surveys of clinic staff, in-person observation, and data collection and analysis, the capstone team was able to understand the pandemic's impact on the clinic's patient flow and identify key problem areas at each stage in the appointment process. The team then used these insights to develop informed recommendations for these pain points. The second phase of the project consisted of formulating trials within UVA health restrictions and guidelines to test the impact of our recommendations. Through a pilot of a new remote registration process, on-time patients increased from 68% to 75%, nurse perceived workload decreased significantly, and the arrival process became more predictable. From this work, the team was able to develop a more generic framework for how health systems might assess and address patient flow issues under normal circumstances as well as during future pandemics.

Keywords—COVID-19, Coronavirus, Patient Flow, Systems Approach, Optimization

I. Introduction

The COVID-19 pandemic has drastically affected healthcare systems and disrupted patient flow processes due to the influx of COVID-related visits and efforts to mitigate the spread of the virus. While much focus has been put on COVID infected patients, vaccine rollout, testing, and critical COVID care, the operations of normal outpatient clinics have also been affected, with many outpatient clinics implementing new protocols that maximize social distancing of patients. As a result, there has been an increasing need to determine how to optimize patient flow under these new COVID guidelines and requirements. To understand this problem, the team focused on patient flow in the University Physicians Charlottesville (UPC) General Internal Medicine Clinic at the University of Virginia (UVA) located in building 415, Suite 2100 at the Fontaine Research Park. It is important to note that Suite 2100 contains multiple clinics – namely, UPC, Endocrine, and Rheumatology – as well as a Phlebotomy lab, all of which share a waiting room. The scope of this project is primarily limited to UPC alone.

At the beginning of the COVID-19 pandemic in March 2020, the UVA Health System faced many challenges as efforts were made to limit the spread of COVID. An article from the UVA Newsroom details COVID's impact from March to April of 2020: "…hundreds of inpatient beds have been regularly unoccupied, surgeries have declined by 70%, and the clinic visits have been reduced by 90%. The result has been a fall in revenue from clinical care and related services that is producing a deficit of $85 million a month" [1]. As part of this response, the UVA Health System enacted new guidelines for ambulatory visits to reduce the number of patients in buildings and ensure a safe environment for patients and providers. These guidelines included prioritizing the use of telemedicine appointments for non-urgent visits and implementing COVID-19 mitigation procedures for in-person appointments, such as requiring social distancing, masks wearing, and patient screening [2]. This new patient admittance process is meant to maximize the safety of patients and providers, but it also makes it difficult for the UVA Health System to operate efficiently. To improve the overall efficiency of the patient admittance process and ensure both staff and patient satisfaction, the team used surveys, data analysis, and observations to identify weaknesses in the existing process and developed solutions to mitigate the existing issues. Additionally, the team developed a general systems approach that may be applied to other healthcare systems undergoing similar circumstances. It is important to note that this project is a continuation of previous work started during the summer of 2020 (see acknowledgements).

II. Background and Related Works

Much of the literature on patient flow management for outpatient care clinics from before the COVID-19 pandemic focuses primarily on optimizing patient appointment scheduling and simulation modeling. A poorly managed clinic scheduling system is often plagued by inefficiency, most often manifesting itself in the form of patient and provider delays and frustration [3]. Improving patient scheduling oftentimes entails the application of lean thinking – a practice that focuses on optimizing the delivery of a service by iteratively evaluating the current state of the scheduling system, removing any waste or inefficiencies, and implementing an improved solution [3]. Simulation modeling is a useful approach for capturing a complex system and investigating the effectiveness of various improvements [4]. This modeling approach in outpatient clinics empowers healthcare teams to accurately represent the flow of patients through their clinic and test alternatives for improvement in such areas as resource allocation and utilization, scheduling, patient throughput, and more [4]. Additionally, these improvements can then be identified and validated against the simulation by developing a design of experiments [5]. Other literature has focused on the general efficiency of outpatient clinics, such as by staff's electronic record usage [6]. Pandhi et al. identified various pain points in the outpatient clinic system that can be generalized to other clinics: the challenge of customizing existing technology, unique organization cultures in each clinic, operational issues and personnel readiness [6]. These challenges identify socio-technical issues that need to be acknowledged or addressed when considering clinic efficiency.

Due to the unprecedented nature of the COVID-19 pandemic, there is limited literature available on patient flow management under such conditions. The majority of what little literature exists are testimonials of what outpatient practices have found to work by trial and error in their efforts to boost patient throughput while accommodating COVID-19 restrictions. For instance, a survey of private practice dermatologists in various metropolitan areas demonstrated that many have found success in improving their clinical efficiency by employing remote COVID-19 screening, check-in, and triage, by modifying their waiting rooms and scheduling to reduce exposure, and by offering telemedicine as an alternative to in-person visits [7]. Many resources also indicate that the COVID pandemic and phase 1 lockdown negatively affected patient flow in daily routines. A study on the impact on dental treatment procedures by the COVID-19 pandemic found that there was a tremendous decrease in total number of patients in the dental OPD services from the months of March 2020 to May 2020 [8]. The study used the inflow of OPD patients per week over periods of past years, pre-COVID conditions, and during COVID conditions; the researchers were able to prove that there is a statistically significant difference in the average of the means of new patients per week, follow up patients per week, and the total number of patients per week between the three different periods for all types of patients coming through the clinic [8]. The journal provides further evidence of the negative effects of COVID on patient flow in health systems.

III. Methods, Design, and Approach

To understand the current weaknesses in the patient admittance process and improve patient flow for UPC, the team implemented a systems approach. This approach involves iteratively using data exploration and analysis to understand the problem, developing recommendations, and testing the different solutions. As a result, the following section is broken into three primary parts: the current state of the clinic; problem identification; and testing and implementing recommendations.

A. *Preliminary Analysis and Current State*

The effect of COVID-19 on the UPC clinic at the start of the pandemic was immediate and significant. In March and April 2020, the month-over-month decline in patient volume was 49% and 32% respectively (see Fig. 1). Despite substantial gains in year-over-year patient volume in January and February, patient volumes in March and April declined by 38% and 60% respectively, from the same period over 2019 (see Fig. 1).

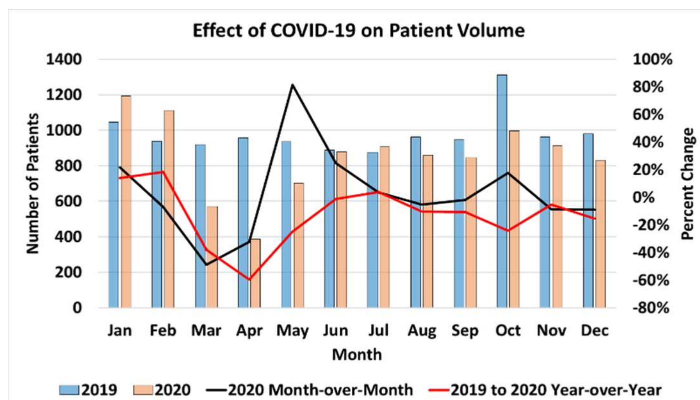

Fig. 1. COVID-19's effect on month-over-month and year-over-year patient volume in the UPC clinic from 2019 to 2020 [9].

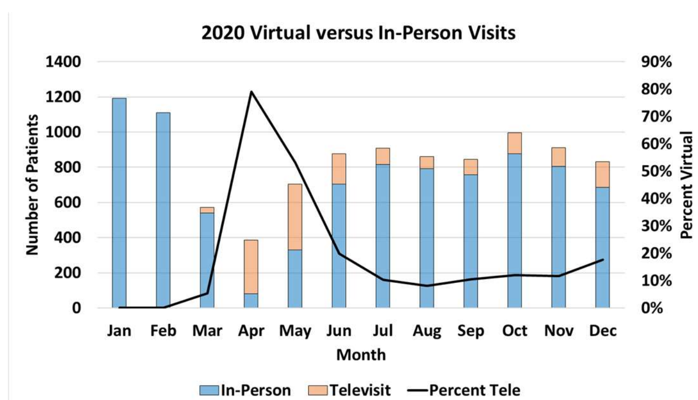

Fig. 2. Percentage of telemedicine visits in the UPC clinic in 2020 [9].

Within weeks, the clinic adopted telemedicine to deliver care remotely, with virtual visits representing more than 50% of visits in April and May (see Fig. 2). Although telemedicine has had a significant presence in the practice since March 2020, patient volumes throughout 2020 consistently fell short of those levels in 2019 – with the exception of July (see Fig. 1 and 2).

The effect of the pandemic on the UPC clinic can be ascertained at a high level from this analysis. In order to establish a current state of processes in the UPC clinic and identify key problems with regard to patient flow management, the team arranged virtual meetings with the clients Dr. Kim Dowdell, primary care doctor and associate professor of internal medicine, and Karen Measells, a senior operations and systems engineer. These initial meetings consisted of walkthroughs of any prior data collection and analysis, an overview of how the clinic operates and its layout, and explanations of current procedures in place. The patient admittance and appointment process in the clinic as of September 2020 can be outlined as follows: a patient remotely registers for their appointment from the parking lot upon arrival, waits to be called up via phone by the clinic staff, enters the building upon receiving the call, is screened in the lobby for COVID symptoms, proceeds to the clinic's reduced-capacity waiting room, checks in at the front desk, is roomed by the nursing staff, completes their appointment, and checks out at the front desk before departing. Much of this process matches the pre-pandemic appointment process, with the key changes being the remote registration, the symptom screening, and a reduced-capacity waiting room. As a result, the appointment process can be summarized by the following stages: scheduling, sign-in/remote registration, check-in, rooming, and check-out.

B. Phase 1 – Problem Identification

The first phase consisted of data collection, observation, and analysis in order to identify the major problems in the existing patient admittance process. To first understand the different elements in the process, the team utilized Epic timestamp data and data collected manually by the team at the clinic. Although this data allowed the team to understand the estimated times associated with different steps in the appointment process, a greater understanding was needed of the specific pain points faced by clinic staff during each stage. Consequently, the team conducted a survey of clinic staff in an effort to better understand the issues of the current appointment process that was instituted in response to COVID-19. This survey broke down response demographics and provided respondent feedback on the different stages of the appointment process. The results of this survey in conjunction with in person observations aided in identifying problem areas and filling in the gaps from data not captured by Epic.

Twenty-eight staff members from Suite 2100 responded to this survey, 42.9% of which were from the UPC clinic [10]. For each stage in the appointment process, respondents were asked to rate the stage on a scale between 1 and 5 with 1 denoting frequent issues and 5 denoting rare-to-no issues. After each rating, they were asked to write in any problems or suggestions for improvement. The distribution of ratings for each step in the process can be seen in Fig. 3. The pain points and opportunities for improvement identified from this survey were for scheduling, sign-in, and rooming stages. These three stages received noticeably lower average and median ratings than the rest. The most consistent problems in the scheduling stage were that mistakes and changes for both in person and telemedicine appointments were frequent and that the current configuration of scheduling impedes workflow and creates inefficiencies within the suite. The most consistent problems in the sign-in stage included challenges calling patients up to the clinic, getting in contact with patients on the phone, and too little time being allotted for patients coming up when called. The survey indicated that staffing shortages and nurses forgetting to call were main contributors. The most salient problems in the rooming stage were long rooming times and inefficient communication amongst staff. These problems were cited as causing significant delays in the appointment process. Despite the higher ratings for check-in and check-out processes, there were frequent mentions of problems, namely confusion on where to go for labs versus check-in and patients forgetting to go through the check-out process before departing.

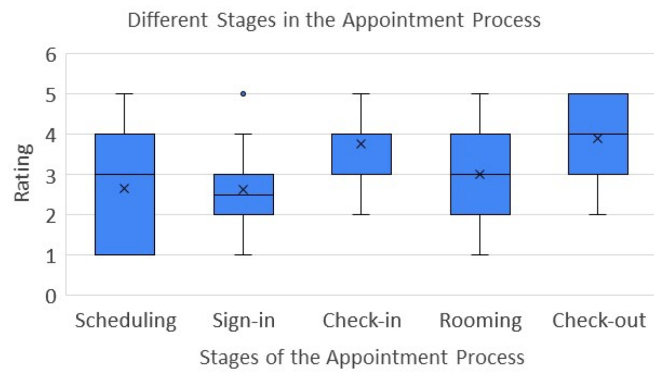

Fig. 3. Boxplots of the ratings for each stage of the appointment process [10].

The team then analyzed the collected data, observations, and discussions with the clients to develop recommendations and inform solutions to the following stages: sign-in/remote registration, check-in and check-out, and rooming. Out of these findings, most notable was a clear difference between patients who remotely registered and patients who registered in person. Fig. 4 shows the distribution of how many minutes patients checked-in at the clinic before their appointment, where a negative number would indicate that the patient checked-in late; the resulting distribution for patients who remotely registered is shifted left, indicating that patients who remotely registered checked-in late more often than those who registered in person.

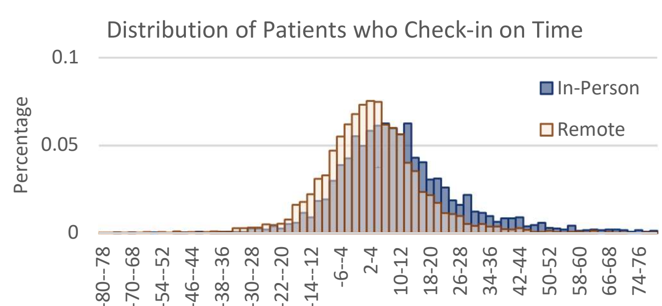

Fig. 4. Difference between how many patients arrive on time by remote and in person remote registration [9].

In addition, a statistically significant smaller proportion of patients who remotely registered checked-in on time compared to those who registered in person ($p < 0.001$). These results reinforce observations by the team and pain points identified by the clinic staff for the sign-in stage. Using the results from observations and data analysis, various weaknesses were identified as well as potential solutions. Table 1 provides a summary of the most salient problems identified in each stage, as well as potential solutions recommended by the team to pilot. Together, these solutions could reduce the volume of UPC patients in the waiting room, decrease variation in check-in to rooming time, and lower overall confusion amongst both staff and patients. All of these issues and possible solutions are addressed in Phase 2 of the project.

Table 1. A breakdown of identified problems and recommendations.

Stage	Problems	Potential Solutions
Sign-in	Patients who register remotely check-in on time less often compared to patients who register in-person Rooming staff struggle to call up patients on time	Pilot a standard time in advance of appointment for patients to come up, bypassing the step of rooming staff calling patients
Check-in	Patient confusion with check-in process, with many lab patients waiting in line for clinic check-in	Improve signage directing clinic and lab patients where to go in suite Provide lab patients with lab instructions at the first-floor registration before proceeding to Suite 2100
Rooming	Poor communication between staff Rooming delays due to lack of staff and variability in rooming times	Change scheduling so that nurses and providers are assigned to particular rooms Assign additional staff to help with rooming
Check-out	Patients forget to check-out at the end of visit	Provide patients with instructions detailing each step of the process the patient must complete prior to departure

C. Phase 2 – Implementtion and Recommendations

After identifying the major weaknesses in the existing patient admittance process, the team was able to develop and implement solutions to address these concerns. This stage consisted of data modeling, prototyping, testing, and final recommendations. Due to the time constraints and scope of the project, not all potential solutions were able to be implemented and tested. As a result, the team focused on improving the issues associated with remote registration during the initial sign-in process. Remote registration is the ideal starting point for improving patient flow due to its importance in mitigating the number of patients in the waiting room, the relationship with remotely registered users checking-in later compared to those who did not remotely register, and the general logistical issues identified by staff with remote registration.

To reduce the complexity of this process, a new procedure was implemented under which patients would be told when registering to come up ten minutes before their appointment time rather than relying on the clinic's nursing staff to call the patients. The ten-minute standard was established via in person, manual observation of the time it took patients to walk from the parking lot to the clinic after being called. After fitting a distribution to the data, it was discovered that a simple ten-minute standard would likely account for over 95% of walkup times without causing delays.[1] To implement this solution, the appointment notes were edited for every patient, notifying the remote registration staff to tell the patient to enter the building ten minutes before their appointment. In the case that a patient never arrives, a rooming nurse will call the patient to let them know they can enter the building. In general, this solution immediately reduced the workload of the clinic's rooming nurses and got patients into the clinic faster. This solution also mitigated issues arising from an inability to contact patients to come into the building who had registered remotely and reduced the proportion of patients who arrived late for appointments after registering remotely.

To measure the effectiveness of this solution, the perceived staff workload was measured before and after the pilot, as well as the waiting time for patients. To analyze the perceived workload, the rooming staff completed a survey adapted from the NASA Task Load Index (TLX) survey, which is a tool designed to assess the perceived workload of individuals [11]. Through this tool, staff were asked to evaluate their mental workload, temporal workload, frustration, effort, and performance on a scale of 1 to 10 for two tasks each day: managing patient arrival to check-in and rooming patients. To consider how staff may have varying opinions of how different categories impact their task load, staff were then asked to rate how much these different categories affected their perceived workload compared to one another. After this, these scores were then aggregated into one weighted score for each day.

The results of this study can be seen in Fig. 6 and Fig. 7, which show the average workload before and after the pilot for each staff member. For both tasks, every staff member's average rating decreased before and after the pilot was implemented. A sign test comparing the averages of each staff member before and after the pilot began was conducted to determine if there was a significant difference in the perceived workload during this period. This resulted in a significant difference between the average workload for managing patient arrival to check-in ($p < 0.05$), but not for rooming patients ($p > 0.35$).[2] This could be expected since the pilot primarily involved remote registration, and not the rooming process. In addition to the workload survey, the number of patients that arrived on time were also evaluated. Analysis of the Epic appointment data from the pilot time frame shows the positive effect of the new procedure with respect to the clinic. Looking

[1] This pilot was implemented using a small dataset due to limited ability to observe the clinic in person. Additional observational data is recommended to identify the optimal standard time for telling patients to come up.

[2] Due to a dataset with only 6 points and the subjectivity involved in staff members assigning weights to the two tasks, there may be a high amount of variability in the results from this statistical test.

at the proportion of patients who check-in on time after remotely registering, the fraction of on-time patients increased significantly from 68% in February before the pilot to 75% in March after the start of the pilot ($p < 0.05$).[3]

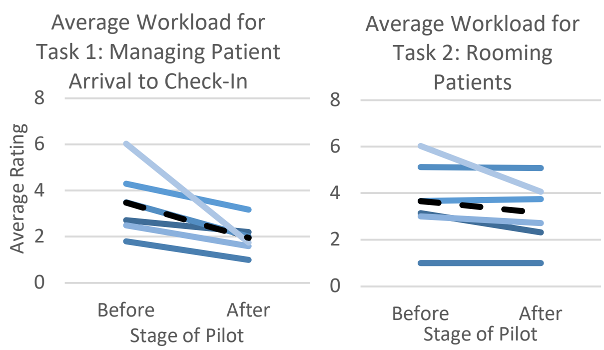

Fig. 5. And Fig. 6. The average workload for each staff member before and after the pilot. The black dashed line represents the average for all staff [12].

Additional solutions were created to address other notable problem areas that were discovered, including patients forgetting to check-out, confusing lab check-in process, and rooming staff support. These solutions could not be implemented due time limitations and difficulties on the management level. In order to address patients forgetting to check-out at the end of their visits, an 'appointment passport' was created. This passport would be given to each patient when they arrived and included tasks to check off as they went through their appointment. These tasks are as follows: asking for prescription refills and vaccinations, discussing MyChart, checking-in at the lab if labs are needed, checking-out, and discussing whether a follow-up appointment is needed. The passport solution aims to correct issues in the data due to missing check-out times by reminding patients to check-out before leaving the building. The number of patients who check-out should increase significantly following the implementation of this solution and this increase would be reflected in the Epic data.

Another solution that could not be implemented is a lab instruction sheet. This sheet would help reduce confusion for lab check-in and prevent patients from waiting for labs without checking-in. The sheet would be provided to all patients who arrive in the building for labs and would have clear instructions for how to check-in for labs, including a diagram of the waiting area. By decreasing the confusion surrounding lab check-in, fewer lab patients will spend time waiting for check-in with the clinic staff, improving patient throughput for both clinic and lab check-in and minimizing patient and staff frustration. In order to analyze the success of this solution, a survey form would be filled out daily by clinic staff and lab technicians to verify the lab instruction sheet is adding efficiency to the process.

Identifying methods to improve rooming inefficiencies was difficult due to the structure of this step in the appointment process. Increasing the efficiency of rooming is important to reduce the number of patients in the waiting room and keep the clinic operating on schedule. To reach this aim, a suggestion was made to utilize a different nursing position when the clinic runs behind schedule. This solution would increase the number of patients who could be roomed at a given time due to the additional nurse. It would also reduce the stress and workload on the other nurses, improving their individual efficiency. Another suggestion to improve the rooming process would be to optimize the clinic's schedule. The inefficiencies in rooming become most noticeable when more patients need to be roomed than there are nurses available at a given time. Therefore, to mitigate this issue, no more appointments can be scheduled at one time than there are rooming nurses scheduled to work that day. This should be incorporated into the schedule optimization as a constraint, which is an area of future work. These two solutions to address rooming inefficiencies should improve patient flow at one of the clinic's primary bottlenecks. This will improve the patient and provider wait times and decrease stress on rooming nurses.

IV. Discussion

From this work, the team was able to develop a more generic framework for how health systems might assess and address patient flow issues under normal circumstances as well as during future pandemics. At a high level, the framework relies on lean thinking and the iterative process of problem identification, analysis, and alternative testing. More specifically, the approach taken in this project can be summarized as follows. First, a descriptive scenario of the medical institution's patient flow process must be established, specifically regarding its primary components and stakeholders. Secondly, one must identify critical problems and parameters through ample observation, surveyal of stakeholders, and data collection and analysis. Once the current state and its problem(s) have been determined, a normative scenario where identified inefficiencies are addressed can be constructed. Various strategies for achieving such a scenario are then investigated via extensive modeling, simulation, and/or piloting of solutions to test the effectiveness of the alternatives. After all these steps have been taken, data-informed recommendations and decisions can be made to improve patient flow.

This project demonstrates, however, just how difficult it is to achieve change and make progress in medical institutions when a public health emergency is in effect. A large portion of time was spent attempting to communicate with health system management. This process was arduous and the reason why many solutions could not be implemented within time constraints. During these times, consistent and active support and participation from necessary stakeholders at all levels of management are imperative to successfully assessing and

[3] To accurately test and assess the change on the system, the clinic would ordinarily return to its pre-pilot procedure after running the pilot for several weeks. In this case, however, the nursing staff were so happy with the change that they insisted on continuing the new procedure.

addressing patient flow issues. Additionally, inconsistencies with timestamps from Epic data impeded the time set aside for data analysis and necessitated time-consuming in person observations to resolve these inconsistencies. Therefore, it is not possible to say definitively that this project achieved the best possible solution, but rather an improvement upon the prior state of the patient admittance process while adhering to restrictions put in place by clinic management. If time allowed, the potential solutions aforementioned (see Table 1) would have been trialed.

There are a multitude of opportunities for future work in patient flow optimization. For instance, as seen in Fig. 6., the team constructed time-series plots of the number of patients from all clinics in Suite 2100's shared waiting room throughout the day from June 2020 to January 2021. Although these plots were primarily used during data exploration to identify times when volumes were historically at the highest risk of exceeding capacity and to discover opportunities for minimizing waiting room congestion in accordance with public health restrictions, they also proved useful in informing and validating an ongoing simulation of Suite 2100's waiting room constructed by Professor Preston White (see acknowledgements). Accordingly, beyond additional trials and analysis, future work in this area might entail further simulation modeling as well as scheduling optimization to explore solutions such as increasing telemedicine during peak times, scheduling more patients during off-peak times, improving staff resource allocation, and requiring lab patients to be scheduled in advance.

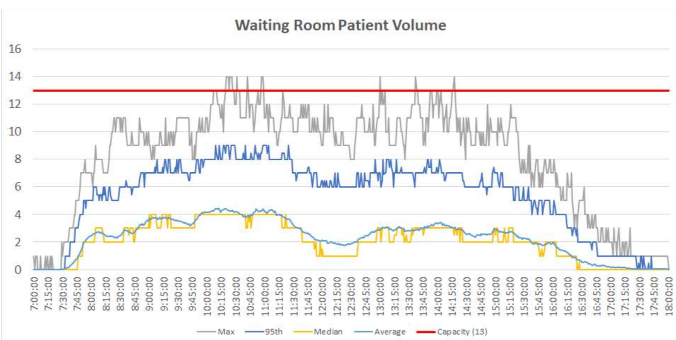

Fig. 7. Time-series plot presenting patient volume in the waiting room of Suite 2100 [9].

According to Fig. 7., waiting room volumes rarely exceeded capacity. It is important to note, however, that these plots were generated using only check-in, rooming, and check-out timestamps from Epic and do not account for several significant determinants of waiting room volumes: namely, the time spent in line waiting for check-in and check-out, the duration of check-out, patients that bring guests, and the presence of lab patients in the waiting room. Data for these factors were unavailable, but in their presence, it can be surmised that these time-series are almost certainly an underestimate of patient volumes, especially since Epic data suggests that labs accounted for over 50% of all visits to Suite 2100 from July 2020 to March 2021.

V. Conclusion

There are a limited number of studies that pertain to the patient admittance processes during pandemics, and of the limited research, many adhere to the following steps: identifying various paint points in the clinic system, attempting to change the rigid scheduling and appointment process put in place, and analyzing the inflow of patients before, during, and after the effects of a pandemic. The developed framework addresses the problem in a similar fashion while including a systems approach. This general framework can be used to address patient admittance processes in future health crises.

Acknowledgments

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References

[1] E. Swensen, "Uva health enacting changes in response to covid-19 financial impact," *UVA Health Newsroom*, Apr. 28, 2020. https://newsrooom.uvahealth.com/2020/04/28/mitigate-financial-impacts-covid-19/ (accesed Nov. 1, 2020).

[2] C. O'Donnell, H. Rojas, and T. Green, "Standard work for ambulatory visits during covid-19 rescheduling office visits and scheduling telemedicine virtual visits (prof remote/non face-to-face encounter)," May 2020, unpublished.

[3] E.M. Wojtys, L. Schley, K.A. Overgaard, and J. Agbabian, "Applying lean techniques to improve the patient scheduline process," *J Healthc Qual,* vol. 31, no. 3, pp. 10-15; quiz 15-16, Jun. 2009, doi: 10.1111/j.1945-1474.2009.00025.x.

[4] S. Norouzzadeh, N. Riebling, L. Carter, J. Conigliaro, and M.E. Doerfler, "Simulation modeling to optimize healthcare delivery in an outpatient clinic," in *2015 Winter Simulation Conference (WSC)*, Dec. 2015, pp. 1355-1366, doi: 10.1109/WSC.2015.7408259.

[5] S. Chand, H. Moskowitz, J.B. Norris, S. Shade, and D.R. Willis, "Improving patient flow at an outpatient clnic: study of sources of variability and improvement factors," *Health Care Manag Sci,* vol. 12, no. 3, pp. 325-340, Sep. 2009, doi: 10.1007/s10729-008-9094-3.

[6] N. Pandhi *et al.*, "Approaches and challenges to optimizing primary care teams' electronic health record usage," *Inform Prim Care*, vol. 21, no. 3, pp. 142-151, 2014, doi: 10.14236/jhi.v21i3.57.

[7] K.M. Yim, R.M. Yim, S. Gaspard, J. MacDougall, and A.W. Armstrong, "Strategies to maximize clinical efficiency while maintaining patient safety during the covid-19 pandemic: an interview-based study from private practice dermatologists," *Journal of Dermatological Treatment,* October 2020, doi: 10.1080/09546634.2020.1836312

[8] L. Ronrang, "Impact on dental treatment procedures in dental OPD attendance and emergency care of non-covid-19 patients during covid-19 pandemic: a study from Meghalaya, India," *Journal of Clinical & Diagnostic Research*, vol. 15, no. 1, Jan. 2021, doi: 10.7860/JCDR/2021/46162.14563.

[9] K. Measells, "Suite 2100 Epic Appointment Data," University of Virginia Health System, 2021, unpublished.

[10] E. Korte, C. Laughlin, T. Peters, and L. Stiles, Feedback on appointment during covid, 2020, unpublished.

[11] Human Performance Resarch Group, *NASA Task Load Index (TLX)*, 1 ed. Accessed: Apr 5, 2021. [Online]. Available https://humansystems.arc.nasa.gov/groups/tlx/downloads/TLX_pappen_manual.pdf.

[12] E. Korte, C. Laughlin, T. Peters, and L. Stiles, F415 UNIV PHYS Workload Survey, 2020, unpublished.