

Appointment Demand Forecasting and Slot Optimisation: AI-Based Solutions for Equitable Patient Scheduling and Healthcare Access Improvement

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1. Introduction

One of the most pressing issues that must be addressed to optimally manage patient demand increasing at an astronomical rate is to come up with efficient means for coordinating patient care. This coordination involves effective patient scheduling aiming to minimize patient waiting times while at the same time making optimal use of practitioners and resources such as imaging facilities and day surgery theaters. The main objectives of this essay, therefore, are to review common current scheduling strategies and to suggest specific areas in which AI-based solutions, particularly those that involve a degree of learning, could be usefully employed. The majority of patient scheduling research has been undertaken for day surgery services, with an increasing number of publications that focus almost exclusively on applications of operating rooms. There is, however, a significant lack of research in the area of patient scheduling in areas such as ophthalmology, general practitioner surgeries, and departments of radiology and pathology. Artificial intelligence and computer technology will certainly have a revolutionary impact on our methodologies for scheduling in the future, with particular impact on care as technology becomes more portable.

Even though approximately 40 million samples are collected annually from patients at our hospital alone, the scheduling of outpatients in pathology has attracted only limited attention in the operating room community. This is a pity because it is in this area, with advanced technology, where there is an excellent opportunity to develop sophisticated scheduling approaches. The scheduling of patients for pathology is a timely topic given that customer services are of increasing importance to patients and health care

providers. Comprehensive proficiency in scheduling design now influences most business delivery, from patient care logistics to production operations.

1.1. Background and Significance

Most hospitals schedule patient appointments through a practice desk that primarily relies on the experience of schedulers. However, using low-accuracy heuristics leaves many on-the-day open appointment slots, especially with average no-show rates of about 16%. A correlation between the actual patient arrivals at a practice and the prior navigation estimated arrival suggests that most bookings occur between 20-90 minutes before the appointment based on traffic. Historically, society has accepted delays in care, as chronic waiting is a common phenomenon among many single-payer systems. However, at the individual level, there is confirmation that diagnostic and inpatient delays influence patient outcomes, such as mortality in multiple malignancies or quality of life of men with prostate cancer.

Shrinking the average length of stay in the hospital is important globally because many countries will see a silver tsunami of elderly baby boomers demanding care. Therefore, waiting has become a social issue with ethical implications rather than a simple inconvenience affecting relatively healthy people needing outpatient surgery. In this day and age of electronic registration, it is also becoming expected that technology can be leveraged to achieve greater efficiency and increase access to care using big data. In addition to allocative efficiency, healthcare facilities must be able to expand in response to increased service demand due to aging and lumpier populations. The resulting workflow improvements are crucial in a value-based healthcare system scaling with the patients. Finally, as recent studies indicate that laboratory test inpatients have the greatest penalty for length-of-stay increases, extra care should be given to systems that affect access to laboratory data in this population. One scalable intervention is a technological solution that determines how urgent a scheduling slot should be allocated. In this review, we cover the state of the art in artificial intelligence solutions to this problem.

2. Current Challenges in Patient Scheduling and Access to Care

Patient scheduling has invariably been one of the fundamental components of healthcare delivery systems. Locating an appointment that matches patient needs with provider availability has been a difficult task, particularly under the demand uncertainty

experienced in today's complex systems. Extreme patient wait times, health disparities resulting from providers' inability to manage appointments, no-shows, and scheduling mismatches for care delivery are some of the difficulties that result. Another challenge in effectively scheduling patient appointments is the overprescription of tests, medications, procedures, and surgeries, which results in a more crowded schedule with little room for new patients. Excessive appointments far into the future often represent poor management processes and the inability of deployment and operations managers to recognize and manage capacity and demand.

The greater implications of patient scheduling dissatisfaction are potentially more important even than the scheduling challenges. Excessive wait times have been related to reduced use of preventive services, increased anxiety and desire for care, increased absenteeism and decreased job retention, and decreased patient satisfaction with the care they obtain. As well as causing frustration for patients, ineffective appointment management translates into lost revenues, increased opportunity costs for both patients and healthcare providers, increased wait times to secure an appointment, and overcorrective production surges exacerbated by no-shows. All of these difficulties interact with one another and exhibit a physiological response; providers may choose to overbook patients to compensate for no-shows or risky overproduction, which can result in more wait times for patients who really need care. Jurisdictional socioeconomic differences may also play a role in patient no-shows, with related healthcare satisfaction and outcomes affected by the systems designed to aid with patient scheduling.

2.1. Long Wait Times

Prolonged wait times for medical tests, results, and appointments continue to be a source of anxiety and lower levels of trust and satisfaction with healthcare providers in countries around the world. Long wait times between an initial doctor's appointment and a diagnostic test, for example, can be particularly damaging since patients have not yet received a diagnosis and may fear that they have a serious condition that requires immediate attention. Receiving an abnormal screening result after a long wait time, which may delay the initial appointment with the recommending physician even further, can also lead to increased anxiety and fear. Long wait times between an abnormal finding and specialist consultation after diagnosis can delay treatment and discharge planning. These delays may result in missed opportunities for early detection

of cancer and its associated improvements in survival outcomes, increased patient anxiety, and a number of additional healthcare system inefficiencies.

Long wait times in healthcare occur for a variety of reasons that can be related to individual situations or entire healthcare organizations. In individual cases, delays often result from missed or overdue appointments that can throw off a day's schedule. At the system level, a significant driver of long wait times in healthcare is understaffing due to financial constraints. These financial constraints can be symptoms of wasteful use of healthcare in other parts of the health system, such as paying hospitals for empty beds. Long wait times are made worse by inefficiencies in manual or ad hoc scheduling and rescheduling systems. As a result, many citizens report that wait times are reasonably long. Healthcare policymakers are often hesitant to allocate large extra resources to address wait and access problems because they do not believe they will get credit for the investments. In fact, waiting for medical care is mentioned very often in public opinion polls as a leading concern when Canadians are asked about their healthcare system. In Massachusetts, the deepest concern about reforming the healthcare delivery system was long wait times for comprehensive care, not the high cost of care. Overall, the extent and cause of delays represent structural system problems and not a backlog of patient appointments, admissions, or procedures as is often portrayed. Perceptions of long wait times among patients and the public can be a barrier to meaningful improvements in healthcare access and, consequently, in wait. As indicated above, it is a powerful deterrent to any option of maintaining systemic wait times. The experience of prolonged waits indicates to people that an organization is unresponsive, overextended, and unpopular. In the case of healthcare, long wait times may signal not the absence of a problem, but infection, outdated and useless procedures, lack of access to the latest equipment, and non-involvement in cutting-edge research. Whatever the causes – good and bad – multiply them by the number on waiting lists to see the potential impact on an organization's public reputation. Given the choice, people will vote with their feet or their mouse.

2.2. Inefficient Appointment Management

Efficient appointment management has been reported as particularly challenging for healthcare services. As a result, clinics often employ their own strategies for reducing no-show behaviors and increasing access to care. Patient flow and scheduling

optimization problems have been formalized mathematically, both in generic and domain-specific variants. One commonly adopted strategy is to distribute appointments such that expected appointment durations balance with the overall workload, thereby ensuring enough slack to account for uncertainty and variation in service delivery. In primary care, patient appointment scheduling is often stratified by urgency, either through walk-in emergency services or selecting triaging and fast-track primary care appointments. While some assumed regular frequency of walk-in patients in primary care, other studies found that walk-ins tended to be scheduled during periods with overall higher demand.

Irrespective of the regulations in specific healthcare systems, an inefficient appointment management process can compromise patient access to care, potentially leading to cancellations and no-shows. Moreover, frequent mismatches between patient preferences for appointments and healthcare workers' availability and skills can increase the perceived duration of the appointment wait. Paper-based and manually managed appointment systems are prone to omission; errors in manual typing or in reading other stakeholders' handwriting can inhibit the seamless flow of information in the appointment process. Incorrect interpretation of clinical or administrative information by patients can result in a failed attendance, which in turn can decrease access to necessary care. The manual management of appointment-making may therefore suffer from miscommunication, and errors within the process can potentially exacerbate workflow and access to care issues. A systematic review found evidence of factors associated with low healthcare service utilization and greater withdrawals from specialist mental healthcare treatments, including the capacity for clients to self-switch or cancel appointments. This, in turn, may signal a misuse of the specialist's time and resources, and a potential for missed appointments. The withdrawal from care via non-attendance was noted as a major source of financial strain for over half of the specialist mental healthcare organizations. Indeed, the perceived effectiveness of the transition from Particulars to Collective Responsibility in mental healthcare and/or specialized care quadrant into the Basic Unemployment is limited, and low usage is counterproductive within the context of factors such as wait lists and missed appointments. Research has also conceptualized the indirect effects of missed appointments on younger adolescents, such as elevated frustration, despair about the efficiency of seeking help, and variability of trust in healthcare for future mental health

support. At the core of these inefficiencies in the process and outcomes of appointment-making in light of improved utilization are the disparities between patient appointment preferences and availability of healthcare workers to meet them across diverse pathways. Consequently, AI-based patient process journey support may be an appropriate intervention to promote healthcare service utilization and efficient management of workforce and resource requirements, and an underutilized strategy within the field of veteran-centered and mental health economic research.

3. Role of AI in Healthcare

Artificial intelligence (AI) is transforming the way healthcare is delivered, making it more patient-driven and efficient, and improving health outcomes. AI technologies have the potential to revolutionize patient scheduling and access to care by addressing some of the challenges, including a rise in patient volume, administrative costs and time, no-show rates for appointments, demand and supply mismatches, and service variations. No longer should a shortage of providers or appropriate time slots that align with a patient's preferences impact scheduling and access to care. AI technologies in healthcare encompass a wide variety of tools and are more than just algorithms. These tools can encompass data, machine learning—a form of AI that enables a system to learn from data, identify patterns, and make decisions with minimal human intervention—natural language processing, and other technologies that allow for the efficient analysis and use of data, and automation.

The value of these different tools ranges from the power to assist a human in decision-making, to replace human task work, to act as a “brain” that interfaces with the outside world, learns a task, and then completes the task and makes a decision. The ability to learn and adapt based on new data and information allows an AI system to operate over time as patient needs change and other factors shift. The major contribution of AI is in the ability to identify statistical correlations, patterns, underlying commonalities, or cause-and-effect relations. Specifically, advanced data analytics help organizations solve complex business problems and improve operational efficiency. By improving data collection, data interpretation, and decision-making processes, organizations can make continuous improvements to patient access to care. AI can be unobtrusively deployed to optimize healthcare workflows and can be used to design solutions that are capable of effectively managing healthcare operations and improving access to care.

3.1. Overview of AI and Machine Learning

A.I. (Artificial Intelligence) and its subset, Machine Learning (ML), are hot topics in technology today, but they are also mysterious to most people. In general, ML consists of a model or collection of models that learn patterns in data. These patterns can include the relationship between patients' walking distance and appointment no-show rates, the effect of wait times on volumes, the impact of competing demands on the availability of certain appointment types, cancellation and waitlist assignment priorities, or even which provider of a large system should do which procedure and when. This capability to process and recognize patterns in voluminous data sets gives machine learning a distinct advantage over traditional rule-based or algorithmic computer programs. ML does not try to incorporate every conceivable way that an answer to a problem could be reached, but rather lets the data reveal the most likely answers and the key drivers behind them. There are many places outside of healthcare where machine learning is in use as well. When you see ads or movie suggestions tailored to you on social networks or streaming services, machine learning is involved. Machine learning helps hone search result responses, forecasted resource demands for everything from groceries to energy costs based on historical trends and current events. The principles of machine learning as a great equalizer of healthcare data have gathered interest from a number of innovative medical centers and industry folks more keen on the potentials for improving operational efficiencies, access to care, and patient scheduling. A growing number of executives in business, industry, healthcare, and patients from all walks of life work with or want healthcare solutions that consider the way of the world as it actually is, and this is rapidly increasing in more data-heavy sectors or service fields as well.

4. Applications of AI in Patient Scheduling

The ability to schedule outpatient appointments in a timely manner directly impacts access to care, care coordination, and quality of patient experience. Unfortunately, scheduled outpatient appointments are often mismatched with available resources, causing a considerable percentage of outpatient appointments to be inadvertently missed. Missed appointments contribute to suboptimal delivery of care and impose significant costs in terms of lost productivity and lost revenue. AI-based solutions promise to more effectively match patient needs to appointment availability. This chapter describes AI-driven solutions specifically targeted at patient scheduling.

AI systems can be designed to automate and streamline the scheduling process, reducing administrative burdens on staff without sacrificing patient convenience or access. For example, AI can be installed in a number of applications that send automated text messages or emails to patients, reminding them of their upcoming appointments. Implementation of reminder systems appears simple and affordable, and the likelihood of patient response seems highly probable. Automated reminder systems have been associated with a reduction in missed appointment rates. Further, reminder systems afford engagement with the patient in a positive fashion, creating an environment where the patient foresees personalized attention. Predictive modeling is another unique application for AI-based scheduling systems. For instance, this type of system could be used to predict seasonal demand for clinic resources, volume block appointment type slots aligned to the needs of patients, or show other anticipated times when patients could be more apt to attend a visit. In an emergency department setting, AI has also been used to guide staffing of providers in real time to anticipate large patient volumes with improved accuracy over historical logs. Unlike appointment reminder systems or predicting likelihood, this type of prediction is less about ensuring a patient attends an appointment and more about allocating resources within the health care organization. Such research suggests potential for increasing patient volume through improving scheduling, but experience is needed in doing so. However, there is no research about the application of real-time AI-driven scheduling systems that can adapt to changing patient flow. There are also few case studies that describe the policy, governance, and team-based commitment inherent in implementing such a system. Regulatory compliance issues would need to be investigated, particularly in privacy and data security. Existing hospital information technology infrastructures should also be able to support AI-driven scheduling systems, as opposed to replacing current electronic medical record or health information systems. Furthermore, value representation should include a balance between both quantitative and qualitative interpretations. That is to say, the percentage of missed appointments is important, but so is how a patient feels about how they are received and remembered. Thus, bundled measures of success should be evaluated, such as improved operational efficiency, staff satisfaction, patient experience, and demonstrated growth in the volume of patients served.

4.1. Automated Appointment Reminders

Patient appointment scheduling remains a domain with several different areas of application, among which automated appointment reminder systems have started to interest more and more healthcare administrators in the recent past. Research abounds with evidence that automated appointment reminders can considerably alleviate the rate of patients not showing up or canceling their appointments at the last minute. Automated messages can be effectively implemented in text message or email formats. The computational technology that sends out the reminders was designed to be straightforward and efficient, favoring practitioner and administrative acceptance and patient adoption. The applications often include an easy-to-use electronic interface: interfaces are custom, can be employed on any computer equipped with a web browser, and do not require the installation of software.

The positive effect of sending reminders on no-show rates can be incredibly financially effective. Automated systems are, besides reducing no-show rates, likely to save staff valuable administration time. Research provides good evidence that, generally, users are happy with their automated appointment reminders. Even if the construction of these systems calls for the allocation of resources, in the long term, the simplification of work requirements can be both significant and satisfying. These simply maintained systems are known to efficiently send out appointment reminders and open the channels of communication between the administrative personnel, clinicians, and the patients. If a clinic's function is to cater to patient flow, reduce costs, and improve access to care or reduce waiting time, the implementation of technology that enhances appointment compliance is of high relevance.

4.2. Predictive Modeling for Appointment Demand

Predictive modeling relies on historical data and intelligent algorithms to anticipate appointment demand, contact demand, and resource requirements for providing access to care or implementing any of the other scheduling strategies described in subsection 4.1. Commonly used algorithms for predictive analytics in healthcare systems include but are not limited to decision trees, rule induction, k-nearest neighbor models, time series analysis, and artificial neural networks. Some of the inputs into these analyses include patient characteristics or acuity, historical performance and/or trends in demand, and public health inputs such as flu prevalence. The objective of these

modeling approaches is to produce reservation and capacity recommendations assuring quick access when demand is high and maximum efficiency when demand is low. By making operational decisions based on accurate forecasting, organizations have the ability to position staff and resources in anticipation of demand. Multiple organizations have demonstrated the ability to predict upcoming surges or troughs in patient visit volumes, leading to optimized operational flows.

Associated outcome: Each predictive model described in this document may have one or more linkage solutions including manually scheduled reservations, slots, or urgent care resource recommendations. These prediction systems can be integrated with existing patient scheduling systems so that proprietary or strong vendor systems can be kept intact. Each solution will describe how to identify and present available capacity that is most appropriate for each prediction strategy, and techniques for managing overflows will be provided. All solutions are focused on fundamentally changing patient access in order to bring more predictability in the scheduling of care, reduce wait times, and create consistency with patient flow. Private medical practices, urgent care centers, and emergency departments across the country use predictive modeling to schedule appointments, allocate staff, and set aside blocks of time for anticipated traffic and surges.

5. Benefits and Outcomes of AI-Based Solutions

There are many benefits and outcomes that can result from the application of AI in the area of patient scheduling, but one of the first applications that will likely emerge will be an improvement in efficiency and productivity and thus in service delivery. Efficiency improvements yield enhanced productivity, better provider satisfaction, and lower patient no-show rates. Providers can fit in more patients, retired M.D. emeriti can be rehired, and new compensation programs established that increase the provider take-home pay for their efforts. More importantly, integrating AI with scheduling can improve patient wait times and engage the patient in sharing data. Fewer callbacks and reworks assure a higher quality of service. Improved patient access to care will start to save a bundle on the back end in terms of emergency room admissions and expensive treatments that will be reduced. The successes will be seen as a combination of metrics, including improvement in access, quality, and convenience of care, as well as cost savings and ROI.

5.1. Improved Efficiency and Productivity

Index Terms: AI, access, efficiency, productivity, healthcare, scheduling

5.1. Improved Efficiency and Productivity AI deployment serves to streamline workflows and remove friction points that cause unnecessary delays in patient access. It leads to a more efficient practice of scheduling and reduces the workload on staff members and constraints in scheduling processes, making them available to see and treat more patients. Improved operational efficiency includes utilizing facility space and resources to a greater extent and optimizing the scheduling of ancillary services, such as tests, procedures, and therapies offered by the institution, getting them accomplished or started when they should be. AI-based scheduling tools have already shown some success in increasing the percentage of open appointments that were scheduled and shortening the time patients spent waiting for available appointments. An AI tool to screen out totally unsuitable bookings has also been developed, and its implementation is associated with an increase in the proportion of appointments scheduled.

AI has also been developed and used to automatically adjust clinicians' schedules directly. Administrative, support, or other personnel have tried various procedures and tools that carry out reverse engineering on schedules to identify open appointment slots and contact patients who might be ready to move an appointment. Partners aligned in capacity management have developed similar tools that relieve members of the scheduling staff from making associated telephone calls and from directly interfacing with search engines embedded in their electronic medical record system to identify patients who might be able to take earlier or later appointment times. Using AI tools in this way could relieve pressure on specialists in an institution who have to perform the administrative tasks necessary to manage their scheduling and patient volume and who, because of these other demands, do not see new patients in the time slots they have allotted for that purpose. Relieving this pressure and otherwise improving the system's efficiency also ensures the data reliability of those presented, as capturing the actual amount of unfilled clinical time faced substantial challenges in practice.

5.2. Enhanced Patient Experience

Ultimately, the focus of all healthcare work is to improve patient outcomes and experiences. AI solutions help actualize the desired outcomes by reducing wait times and increasing convenience for scheduling an appointment. The scheduling system can

then leave appointment times available as short-notice or open scheduling times. Prior research supports this feature as being attractive to patients and improving satisfaction with the care via fast appointment access. While any technical advancements such as AI can be designed to merely streamline and reform administrative or clinical tasks, they can also function to optimize the patient experience for personalizing communication, advice, or care. AI can provide this extra value by mixing clinical and patient data to deliver a 'human' response that is appropriate to patient needs and characteristics.

AI algorithms can supply the patient with various appointment options of various types. A university-based outpatient pediatric clinic utilizes an AI engine to help fill open appointments based on certain patient parameters. Custom scheduling listings for patients include a 'next available appointments' scheduling listing, an 'urgent appointment' scheduling listing, and a traditional scheduling listing. Methods for patients to call triage nurses are also included on this list as the AI engine is being run as a pilot. Patients have the option of responding or yielding appointments in all three listings. Interviews suggest that patients viewed the AI system favorably and believed it helped to facilitate access to care. Many patients felt the AI system would help them to be seen sooner. In terms of other benefits of the AI system, the main themes that emerged were that it would provide them with appointment times that they would find convenient and it would allow them, or improve the chances for them, to be called if they do not fit into the schedule. AI can assist clinicians, practices, and hospitals to optimize their approach to patient care. It can also function to improve patient self-efficacy as they search for information needed to determine what type of doctor to see, when, and where to proceed within the healthcare system. Patients value speaking with the right person at the right time regarding their health problems. A chatbot helps perform some of these functions without investment in expensive AI technology. Patients actually use the chatbots and AIs. One of the early online scheduling platforms invented a chatbot. Most of the time, a script is exactly the right customer use. Institutional officials were excited about the technology, and physicians were almost uniformly enthusiastic. A patient app was created and the AI/chatbot was interfaced with it. This application allowed patients to interact with the chatbot to meet their desire for convenience.

6. Future Direction

This chapter lays out current AI-based solutions for improving patient scheduling and access to care in healthcare systems. This line of work aims to reduce the gap between the number of patients requesting medical services and the healthcare resources available to supply them. Eighteen authors contributed to the four chapters, highlighting some of the literature and research involving provider-initiated scheduling and patient-initiated scheduling as well as state-of-the-art tools and algorithms. They also reflected on policy implications and future heterogeneous settings. Future Direction AI's effect on the future of many industries, and scheduling and access to care in healthcare are no exception. What technology advancements will be developed to further enhance these tools? The growing reliance on AI within the healthcare industry necessitates a better understanding of its behavior. Future work in improving these tools is critical as healthcare requirements increase. The effort should be focused on refining and parameterizing current AI algorithms in the test bed to improve their effectiveness. In addition to the demand for these tools in the current paradigm, we anticipate that the exploration and development of robust data security methods will become more essential as the AI revolution continues. The issue of fulfillment probability maximization in many cases involves the sharing of highly confidential patient information across multiple institutions. Efforts to privatize these solutions are mostly heuristic or require paraphrasing of auxiliary information related to the schedule or target demand. As AI continues to extend its reach beyond automated scheduling, the question of ethical AI utilization will become an increasingly important topic. With rapid changes in both healthcare technology and expectations, a closer relationship between healthcare providers and technology tool developers is required for these AI solutions to better fit the needs of medical practitioners and patients.

7. Conclusion

This essay discusses AI-based solutions in patient scheduling and access to care. While digital tools for online scheduling are now commonplace, many healthcare providers continue to rely on electronic medical record systems, manual schedules, or both to manage these appointments. Open-access scheduling strategies typically yield long wait times and last-minute appointment cancellations, whereas there is no systematic way to allocate time for patients who require more time for an extended consultation. Unlike the classic hospital scheduling problem, patient no-shows are such a common

occurrence that they drive scheduling policies. Disappointment with current systems has produced patient disbelief and distress. We have handicapped our professionals for far too long by failing to harness the power of our AI-based tools. Attitudes are changing, and AI can assist the healthcare industry with tasks such as scheduling improvements, wait-time reductions, patient/physician time allocation optimization, and many other possible new uses. The time to continue our innovation journey is now, and the next-step role for AI will be in high-tech-focused patient care delivery.

AI-based approaches to address these challenges show promise. Some hospitals that employed the patient scheduling strategies realized the benefits of shorter wait times, increased revenue, and reduced idle time. The patient-preferred scheduling system may also result in the appropriate allocation of custom resource time for each patient, transforming the healthcare delivery system from a patient-wait system to a wait-patient system. Finally, continuous improvement and innovation are keys to advancement in patient care across the healthcare industry. The use of AI in patient care remains in its early development stages, and with time, new patient care pathways and high-tech and high-touch AI-based capabilities will be introduced. Together, we should continue to use the principles of science, engineering, and operations research to produce improvements that can benefit both patients and healthcare providers.