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Digital triage: Novel strategies for population health management in response to the COVID-19 pandemic

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ABSTRACT

The COVID-19 pandemic has created unique challenges for the U.S. healthcare system due to the staggering mismatch between healthcare system capacity and patient demand.

The healthcare industry has been a relatively slow adopter of digital innovation due to the conventional belief that humans need to be at the center of healthcare delivery tasks. However, in the setting of the COVID-19 pandemic, artificial intelligence (AI) may be used to carry out specific tasks such as pre-hospital triage and enable clinicians to deliver care at scale.

Recognizing that the majority of COVID-19 cases are mild and do not require hospitalization, Partners HealthCare (now Mass General Brigham) implemented a digitally-automated pre-hospital triage solution to direct patients to the appropriate care setting before they showed up at the emergency department and clinics, which would otherwise consume resources, expose other patients and staff to potential viral transmission, and further exacerbate supply-and-demand mismatching.

Although the use of AI has been well-established in other industries to optimize supply and demand matching, the introduction of AI to perform tasks remotely that were traditionally performed in-person by clinical staff represents a significant milestone in healthcare operations strategy.

1. Background

Coronavirus disease 2019 (COVID-19) is a new disease that has yet to be fully understood. Patients with COVID-19 develop a myriad of signs and symptoms of variable severity that mimic many other diseases, such

as the common cold or influenza. Patients, healthcare providers, and the public still have more questions than answers regarding this disease, its full spectrum of pathologic manifestations and its epidemiology.

The COVID-19 pandemic has created extraordinary challenges for the U.S. healthcare system due to the overwhelming mismatch between

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healthcare system capacity and surges in patient demand. Historically, the ability of healthcare systems to grow in response to demand has been constrained by the linear rate at which systems can train, organize, and deploy human labor.¹ However, the exponential rate at which SARS-CoV-2 spreads threatens to overtake that incremental pace of growth.²

In addition, widespread shortages of personal protective equipment (PPE) and close, sustained contact with infected patients leads to significant portions of the healthcare workforce being routinely exposed to infection. The combined impact risks decimating the U.S. healthcare workforce.³ Therefore, the task was not merely to stretch hospital capacity to accommodate potential surges of patients, but to do so even as significant portions of the healthcare workforce were quarantined, absent, and ill.^{4,5}

To address these concerns, our organization—Partners HealthCare (now Mass General Brigham) in Boston, Massachusetts—created a set of offerings for patients and the public including a COVID-19 telephone hot-line, robotic process automation (RPA) chatbots, specialized respiratory illness clinics (RICs), drive-through testing sites, surge facilities for acute and post-acute care, and Emergency Department (ED) and inpatient pathways tailored to the unique needs of COVID-19 patients as we grappled with treating this disease at the same time we were learning about it. We describe our efforts using digital technology to adapt to the increase in patient demand for healthcare services during the COVID-19 pandemic, and simultaneously protecting the safety of our healthcare workforce. While there was concomitant rapid expansion of virtual alternatives to in-person encounters and workflows, we focus here on the use of simple artificial intelligence (AI) in the form of robotic process automation as a digital pre-hospital triage tool for population health management.^{6,7}

RPA technology is considered a form of expert system and one of the foundational tools in AI by leading experts.¹ RPA chat bots and branching logic bots are formally considered simple (or “weak”) AI. Simple AI can have powerful effects in managing big problems, including the COVID-19 pandemic. Our COVID-19 RPA tool emulates the decision-making ability of a human expert designed to navigate complex triage problems on massive scale using if-then algorithmic branching logic rules. The expertise in our COVID-19 screener is found in the depth and complexity of work that went into the design of the clinical pathways (reassurance vs. quarantine vs. refer patient to the nurse hotline or a telemedicine consult vs. refer to respiratory clinics or the Emergency Department) to siphon through the algorithm to reach a triage end-decision. The goal of this technology was not to perfect the triage of every patient, but rather to capture the large proportion of the worried-well, reassure them, and prevent overburdening the healthcare system and resources. In this way we used our expert RPA system on a grand scale to reduce the noise among the signal processing needed for those who do present to a healthcare facility.

2. Organizational context

Mass General Brigham (MGB), a large academic integrated healthcare system founded by Massachusetts General Hospital and Brigham and Women’s Hospital in 1994, consists of a core network of 11 hospitals, including specialty hospitals for rehabilitation and behavioral health, and a peripheral network of community health centers and urgent care facilities. MGB employs over 74,000 healthcare workers and cares annually for over 1.5 million patients residing in Boston and the New England area.⁸ MGB hospitals are teaching affiliates of Harvard Medical School, serve as tertiary referral centers for the surrounding New England region, and are a national and international destination for patients with advanced, complex, or rare diseases.

In February 2020, U.S. coronavirus cases climbed at an alarming rate. MGB underwent massive re-organization to prepare for the surge of COVID-related cases. Elective surgeries, non-urgent procedures and clinic visits were deferred. Resources were redirected to support

emergency, inpatient general care, and critical care teams on the front lines, in addition to expanding virtual ambulatory care services. Drive-through testing sites, RICs, and surge facilities for acute and post-acute care were established. Many employees were re-assigned roles to supplement departments with the greatest staffing needs. Meeting the demands posed by viral spread necessitated more than re-shuffling of human and physical resources; it required the adoption and development of digital strategies to extend the capacity and scope of the workforce as a whole, including the introduction of AI to supplement human labor. Although companies such as Amazon and Apple routinely utilize AI to manage networks and accomplish service delivery tasks, using an automated chatbot to perform population-level patient triage represented a revolutionary step for a comparatively antiquated U.S. healthcare industry accustomed to traditional analog care delivery within our brick-and-mortar hospital and clinic walls.

3. Problem

The volume of patients at risk for COVID-19 across the MGB enterprise was anticipated to be large, but data from early epicenters in China suggested that the majority of infected patients do not require hospital-level of care: 81% suffered only mild symptoms, 14% required urgent supportive care, and 5% required critical care and support such as mechanical ventilation.⁹ Stratifying patients into broad categories of illness severity framed this as a problem of signal processing for population health management: despite large amounts of incoming data and patient requests, the majority of mildly ill and healthy-but-anxious patients represented the predominant “noise” that could be safely filtered and managed remotely through automated algorithms while more acutely ill patients represented the “signal” that we sought to capture and direct to the most appropriate higher level of care.

Applying these signal processing principles to the 1.5 million patients in the MGB network and to new patients entering our care, hospital leaders sought to develop a system of pre-hospital triage that could direct patients to the most appropriate care setting *before* presenting to the emergency department. This would allow for more efficient patient-centered care, prevent unnecessary exposures, and ensure adequate access to a strained PPE supply chain for our staff. This triage system would have to handle inquiries from existing MGB patients, MGB employees, and the general public and route through existing (ambulatory clinics, virtual urgent care (MGB on Demand)) and new (telephone hotline and chatbot) care settings. A standardized testing and triage algorithm would underlie the system to distinguish between patients needing testing and patients who could be safely reassured to manage mild symptoms with self-quarantine at home from those patients requiring more thorough medical evaluations and in-person care [Fig. 1].

On March 9, 2020, MGB established a COVID-19 telephone hotline. Patients and community members could call to discuss symptoms and concerns with MGB nurses. The goal was to identify and reassure the approximately 80% of patients who could be safely managed with quarantine at home due to mild symptoms and low risk of exposure or progression to severe illness, and to guide the 20% of sicker, higher-risk patients to additional care: drive-through testing facilities, primary care providers, virtual urgent care, and in-person evaluation at RICs [Fig. 1]. Patients with severe symptoms such as chest pain, shortness of breath, loss of consciousness, or emergent conditions such as acute cerebrovascular disease were expedited to the ED.

Within the first week of going live, hotline call volume grew to over 2,000 calls per day. Nurse operators discovered that the majority of callers fell into two categories, each requiring different triage approaches and time to address their concerns. One category sought guidance about how to stay healthy in the midst of the pandemic, so nurses counseled these patients about social distancing, self-quarantine, and infection prevention. The other category had active symptoms or potential exposures and sought diagnostic testing guidance or medical

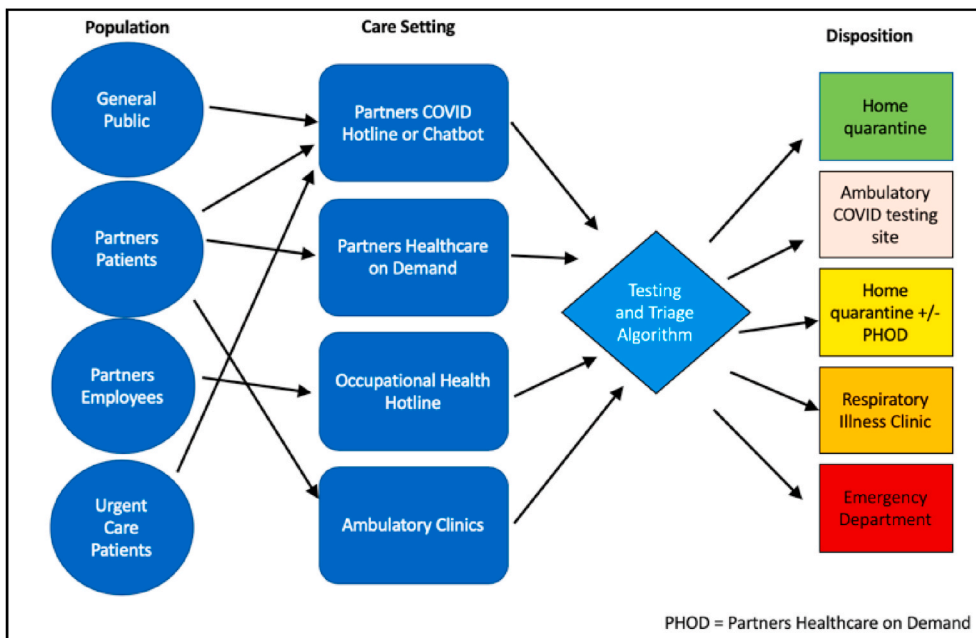


Fig. 1. Mass General Brigham pre-hospital COVID-19 triage system which receives inquiries from different populations through a combination of existing and new care settings. A standardized testing and triage algorithm ensures common, evidence-based testing and disposition recommendations across all care settings. The triage algorithm was developed based on resource availability and guidelines from the CDC, Massachusetts Department of Public Health, and MGB’s expert input, as well as patient risk factors to determine how patients would be directed to the most appropriate end-disposition point. PHOD = Partners (now MGB) Healthcare on Demand (virtual urgent care).

evaluation arrangements.

Despite the best efforts of hotline staff, average wait times increased, peaking at 30 minutes; up to 50% abandoned calls before staff could get to them [Fig. 2]. If the hotline remained congested with “worried-well” callers, sicker patients would abandon calls before connecting to necessary care. Callers dissatisfied with long wait times might show up unannounced at emergency departments and put themselves, other patients, and healthcare staff at risk of virus exposure without benefitting from hospital-level of care.

A more scalable solution was necessary. MGB began exploring opportunities to digitize the pre-hospital triage system by building an interactive robotic process automation tool, also known as a chatbot, to handle increasing patient volume.

4. Solution

To decompress the COVID-19 hotline, an interdisciplinary team at MGB began exploring AI options to digitize key pre-hospital triage tasks. The MGB team connected with leaders from Microsoft and the Providence St. Joseph Health system in Washington state, the first COVID-19 hotspot in the U.S. Providence collaborated with Microsoft to build an online screening and triage tool to distinguish between patients who were overall well from patients requiring more immediate attention. Providence screened over 40,000 patients in its first week, delivering care on a scale that is otherwise impossible to achieve using traditional clinician-dependent triage pathways.

The MGB team recognized the potential of this type of AI-based solution. They worked with Providence and Microsoft to build a similar COVID-19 screener tool to modify and deploy for MGB patients and the broader regional community of patients seeking triage guidance. This

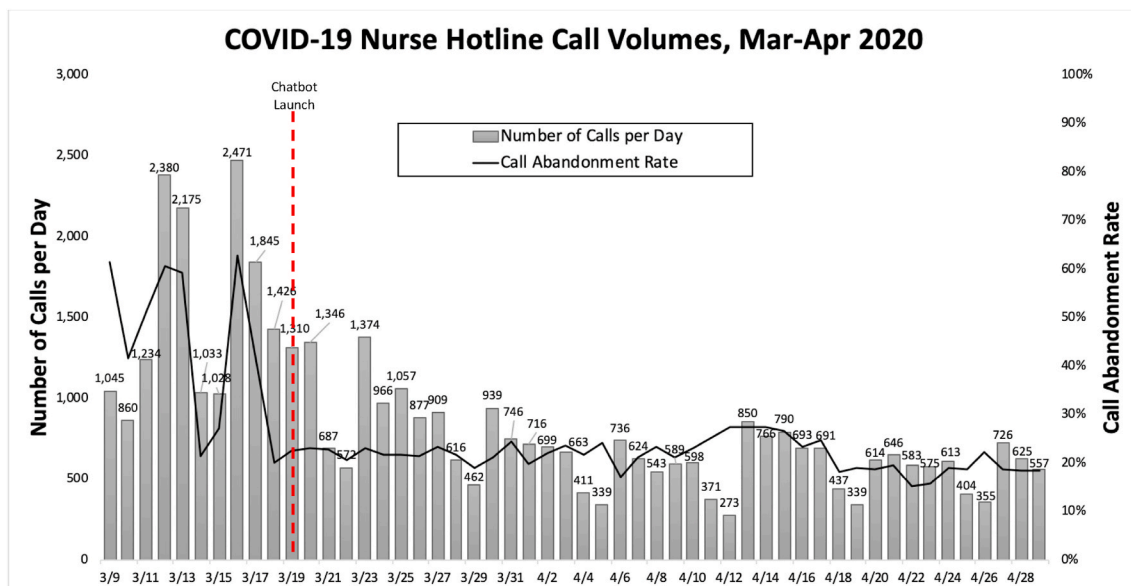


Fig. 2. Covid-19 Nurse Hotline calls per day and caller abandonment rate from the period of March 9, 2020 to April 29, 2020.

screeener uses a mobile-responsive, web-based interface to present users with a series of questions about risk factors and symptoms based on the Centers for Disease Control and Prevention (CDC) guidelines and input parameters from infectious disease experts at MGB in order to capture the initial broad screening categories of risk to determine whether the patient required additional consultation with a COVID-19 expert via the MGB COVID-19 expert either via the COVID-19 hotline, via an on-demand virtual consultation, or in person. Answers fed a decision algorithm to arrive at a disposition endpoint [Fig. 3]. Complexities of subsequent triage and management decisions (gender, age, pre-existing comorbidities) were deliberately handled by a COVID-19 expert clinician if they were directed to this endpoint according to the initial Chatbot algorithm. The screener was also provided in Spanish, as many of our sickest patients originated from primarily Spanish-speaking populations.

The AI chatbot was first deployed via an interactive voice response (IVR) message that COVID-19 hotline callers received while on hold, instructing them to visit the MGB website hosting the chatbot (<https://covidscreener.massgeneralbrigham.org>). At the end of a series of chatbot questions, users were provided with educational material in accordance with CDC guidelines, providing reassurance for the first category of callers, while guiding the second category of callers down the pathway for further clinical evaluation. Using the chatbot while on hold augmented subsequent nurse-hotline conversation efficiency, as the caller and nurse had a shared discussion framework, enabling nurse

operators to quickly triage and determine mutually agreeable plans for self-quarantine, testing, or evaluation. The chatbot was subsequently made available on the MGB website so patients could access it prior to calling the hotline and potentially avoid a call altogether [Fig. 4].

The AI triage tool was designed to screen enormous numbers of people and differentiate the “worried well” from those warranting additional evaluation [Fig. 5]. There was an increased utilization during the period of March–April 2020 reflecting the overall success of the chatbot implemented. Patients needing additional assessment were directed to the hotline clinician to determine where to direct the patient: drive-through testing sites for those who met testing criteria but were well or mildly ill and free of pertinent comorbidities, respiratory illness clinics for those with moderate comorbidities and/or symptoms requiring in-person evaluation, telemedicine consultation with a physician, or proceed immediately to the nearest ED for the severely ill. While the clinician was a critical part of the process, the AI Triage tool decreased the burden of work and serves as an exemplar for the integration of automated technologies into human work flows.

Implementation of this simple AI tool, ubiquitous in e-commerce, represents a radical change in operational strategy for healthcare.¹ By using computer algorithms to perform tasks traditionally performed by humans, hospital systems are disrupting previously ingrained limitations in care delivery strategies. These types of AI and digitally-driven care solutions do not eliminate human-powered workforce needs, but rather augment clinician positioning at the receiving end of patient care,

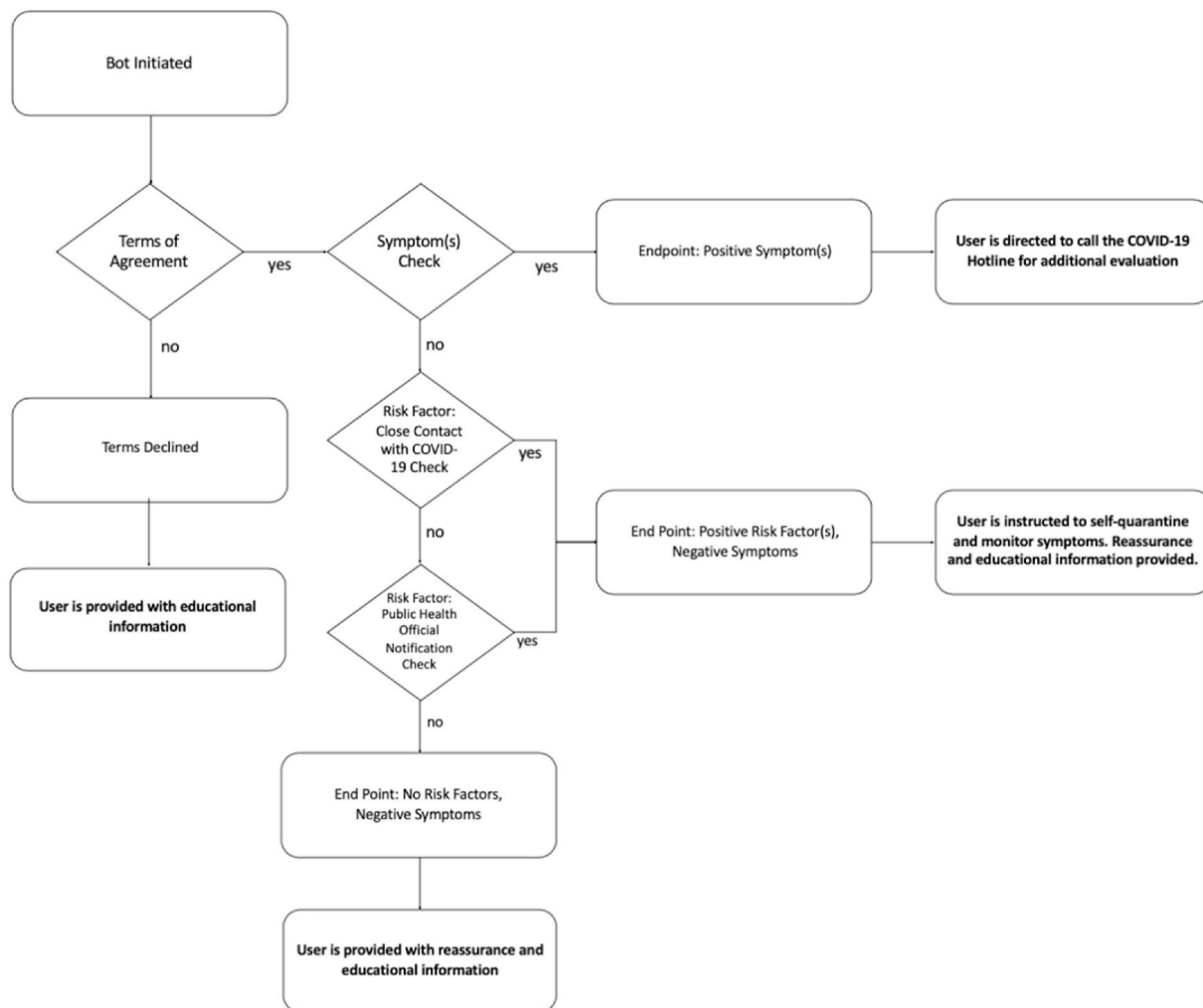


Fig. 3. Mass General Brigham robotic automation process chatbot’s basic clinical decision algorithm upon which more refined algorithmic inputs could be built each day as testing criteria, resources, and parameters changed.

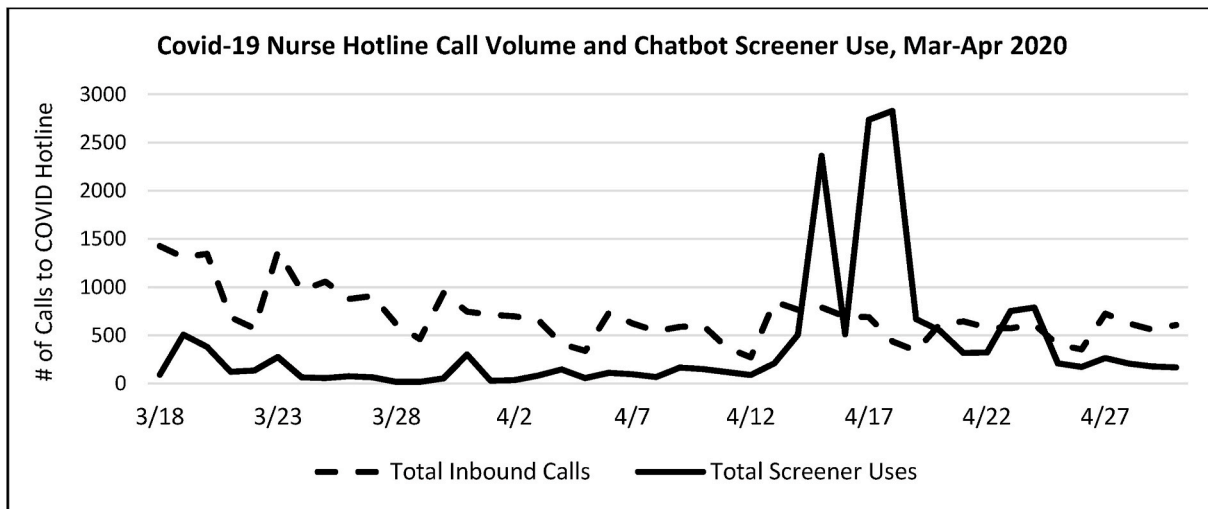


Fig. 4. Covid-19 Nurse Hotline call volume and Chatbot Screener Use, March–April 2020. The chatbot screener use peaked with increased visibility and promotion on the MGB Patient Gateway portal around the same time as COVID + case incidences occurred in the Boston area and as seen in the Mass General Brigham system COVID + inpatient volume.

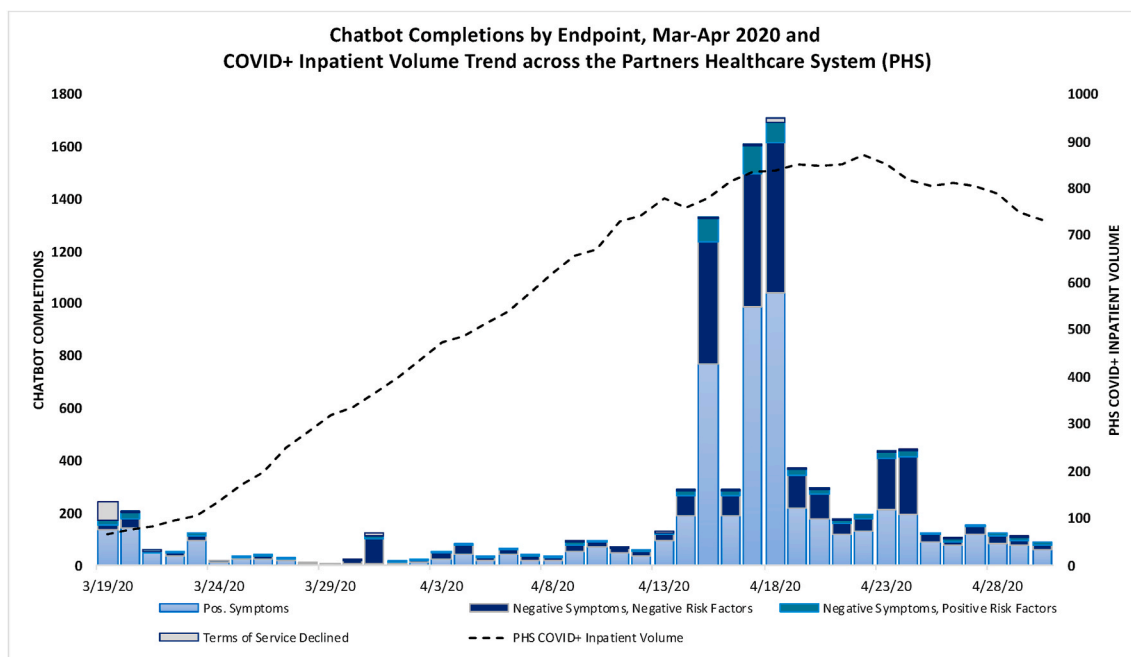


Fig. 5. Chatbot Screener Completions by Endpoint, March–April 2020. Terms of service declined were high on day one as it was in a Beta-launch test phase on that day. The worried well peaked at the same time as the symptomatic population and the COVID + inpatient volume throughout the MGB (formerly Partners Healthcare System (PHS)), emphasizing the importance of utilizing AI during high volumes of case incidences and peak anxiety among the population needing triage.

where ultimate human decision making has even greater impact on ensuring quality and safety.

Combining simple digital technology, a carefully designed clinical process flow with symptom and risk factor scoring, the AI chatbot redirected a portion of patient traffic from the hotline, eliminated rate-limiting bottlenecks for patients, and enabled targeted deployment of precious human expertise to care for the subsets of patients with acute illness. AI thus extended the system’s ability to guide patients to the most appropriate care setting at previously unattainable speeds and precision. Designing MGB’s own version of a chatbot screener allowed for rapidly updating a customized algorithm in the local clinical context of testing availability and evolving clinical guidelines, with disposition endpoints specific to the MGB population and care delivery infrastructure. Google (Verily), Apple, Cleveland Clinic, the CDC, and Buoy Health

developed similar triage chatbots; some integrate the chatbot algorithm directly into care delivery and others do not, demonstrating a variety of algorithms and endpoints matched to the needs of their target populations. Some were updated with more frequency than others based on rapidly evolving information access and resource availability that varied at times on a day-to-day basis.¹⁰

The COVID-19 pandemic has forced healthcare leaders to recognize that many key triage functions can be performed digitally. Doing so at scale enables tailoring of clinical resources, optimal matching of human labor to care for patients requiring higher levels of care including our medically underserved communities that may not have digital access privileges, and stewardship of limited PPE supplies. Minimizing the loss of human life during this pandemic depends not only on public health measures such as social distancing, but also technological innovation to

augment resource utilization and deliver virtual care where possible.

5. Unresolved questions

Introduction of new technology may improve operational efficiency and provoke discussion about the safety, quality, feasibility, and equitability of such interventions. Protocols are needed to monitor outcomes of automated algorithms to ensure they dispense sound, actionable guidance without causing undue harm. Iteration must occur in parallel with evolving clinical contexts and operational parameters (e.g. PPE supply). Clinical experts must own and regulate the underlying AI algorithms. As testing criteria and policies change, algorithms require revisions to ensure they serve as a central source of the most up-to-date information and support top-down enterprise communication. Future chatbot iterations may include remote appointment scheduling and automated referrals to optimize patient flow and minimize crowding during peak congestion.

Prospective dashboard data about inputs and outputs of the algorithms should be collected and analyzed to understand the performance of the algorithms in the context of patient outcomes; insights from such data should be used to improve them. A 2015 audit of 23 different online symptom checkers found significant discrepancy in the triage recommendations provided for the same standardized patient vignette, suggesting that more work is needed to refine the algorithms.¹¹

Web analytics should be used to analyze chatbot traffic trends and click-through user behavior. This could be extrapolated to provide a global understanding of disease emergence trends using predictive analytics. At this time, the MGB chatbot collects anonymous data from users and cannot be linked to patient outcomes. It remains to be seen how willing patients are to adhere to recommendations dispensed by a chatbot, given the traditional emphasis on the doctor-patient relationship in healthcare. Further studies are needed to understand the public perception of AI in medicine and behavioral change.

When piloting a novel operational strategy, we must make conscious efforts to identify and address existing health disparities and ensure health equity as new technologies may risk amplifying these inequities. Many of our most vulnerable patients have limited English proficiency, low technological literacy, and limited access to Internet-enabled devices. Disparities can be minimized by delivering content in multiple languages and utilizing digital platforms that are more universally accessible. Freeing human resources from the constraints of the critical triage pathway enables redeployment of those resources to focus on improving social determinants of health.

There are many opportunities to use AI to align supply-and-demand matching during this pandemic. Emergency medical systems may deploy complaint-base algorithms to divert ambulance traffic. Governments may mandate self-screening via AI-based platforms in order to offload and protect healthcare systems or identify epidemiologic intelligence on early outbreak hotspots. Other possible functions include diagnostic decision tools, delineating sub-profiles of the disease, choice of therapeutics and prognostication, supply chain planning, resource allocation, and staffing management. By strengthening human labor capabilities through artificial intelligence, we can ensure the sustainability of our healthcare system throughout the peak and duration of the surge.⁴

6. Lessons for the field

The healthcare industry has been a slow adopter of digital innovation. Electronic medical record systems have been available since the 1970s, but it was only in 2014 that it become mandatory in the U.S. that all practitioners transition to electronic health records.¹² Some older clinicians still prefer paper.¹³ Now, a global pandemic has forced policy makers, insurers, hospital system leaders, and clinicians to break down archaic barriers and to embrace digital health as a means of improving access to, convenience of, and costs related to care delivery, and is also a

key method in facilitating social distancing.

Some maintain that digitization of clinical practices may dehumanize our medical traditions. The COVID-19 pandemic sheds light on the crucial role that automated critical pathways play to achieve the scale and scope necessary to protect patients and healthcare providers. Re-assigning clinicians as end-receivers of AI-driven triage is a rational approach to extending the capacity of the healthcare system. Through AI, patients are able to access prompt, evidence-based advice and direction to the most appropriate care setting. This minimizes missed opportunities in an overburdened system. Digital strategy highlights the true humanity of the system, by providing the greatest care for the greatest number of people to the greatest of our capabilities.

Author contributions

KAW and LL contributed equally as first authors. KAW, LL and HMZ developed the paper concept. KAW, LL and FZD drafted the manuscript. HMZ, DM and RS provided instrumental data supporting this work. LL, KAW, FZD, RS, YGK, SH, DM, LHS, ABL, and HMZ were instrumental in carrying out iterations of the chatbot for clinical process flow and augmentation over time and providing critical revisions of the manuscript for important intellectual content. LHS, ABL, and HMZ are credited with the conceptualization, technological design, and implementation of the chatbot from the beginning of the work on this project at Partners HealthCare. NW, GZ, ITL, TDS, GZ, RP, and GB were instrumental in implementing the ambulatory triage pathways for COVID patients at Partners and also provided critical revisions of the manuscript for important intellectual content.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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