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Review Article

Artificial Intelligence and Robotics in Delivering Healthcare at the Time of COVID-19 Pandemic

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Abstract

It has been more than six decades since Artificial Intelligence (AI) was introduced to outperform humans in accuracy and speed. Ever since, many algorithms have been developed that gained success in fulfilling the claims of AI. Their high speed and accuracy have made them perfect candidates for substituting humans in many settings. Even though AI has changed the face of many industries, its application in some others is still a subject of debate. Besides AI, which, over decades, has changed the face of industries for good, there is another phenomenon that has changed it: the novel coronavirus (COVID-19) pandemic. Unlike AI, this pandemic has changed every aspect of human life. Due to its fast spread through human contact, stay-in-shelter orders have been placed to slow the person-to-person transmission. This is a source of concern for industries as many of them may fade away due to the pandemic. However, there is one industry at risk of burning out rather than fading away: the healthcare industry. Limited resources, on the one hand, and increased demand, on the other hand, have made the healthcare industry one of the main victims of the pandemic. Emergency departments are flooded with patients, yet non-emergent medical services have been nearly shut down. Therefore, solutions are sought to help both lighten the burden on emergency departments and facilitate providing non-emergent medical services. AI and automated systems can be the key to such solutions. They have proved their efficacy in many instances in the healthcare industry, from emergency department triage to assisting surgeries. Thus far, their widespread use has been halted due to legal and ethical debates. However, the COVID-19 pandemic can be a turning point in the integration of AI into the healthcare system, just as improving AI integration with healthcare can be a turning point in this pandemic. Herein, we overview how AI can help deliver non-emergent medical services during the pandemic and possibly thereafter.

Keywords: Artificial Intelligence; COVID-19 ; SARS-CoV-2; Robotics

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Introduction

Pandemics are not new to humankind; they have been reported from the pre-historian era through the present day. Many of these pandemics are caused by viruses, with members of the Coronaviridae family responsible for a considerable number of them (1). One of the most prominent and debilitating outbreaks caused by a virus from this family is the Coronavirus disease of 2019 (COVID-19) caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The current pandemic caused by the SARS-CoV-2 virus is comparable to the H1N1 pandemic of 1918, also known as the Spanish Flu, in terms of the impacts it made on global levels (2), specifically the speed of spread, number of countries and regions involved, and number of affected individuals. Even though the number of individuals affected by the COVID-19 pandemic has a long way to meet that of the Spanish Flu, the impacts it has made worldwide might be just as severe as that of the Spanish Flu, in part due to the level of globalization in which the COVID-19 pandemic has occurred (3). Therefore, the global condition in which the COVID-19 pandemic has occurred can be considered a curse as it served with the speediness of the spread of the virus, but it can also be a blessing as the technologies in hand can facilitate the combat against this pandemic in different ways (4). When the COVID-19 pandemic started in late 2019, the anticipations regarding its fate were controversial; however, high-tech solutions not only attempted to predict how the pandemic would spread or when it would come to an end, but they can also be accountable for the majority of the progress made in the battle against this pandemic (4). Even though the sacrifices of human experts and first-line responders are undeniable, the high-tech services for this pandemic, from vaccine design to providing patient care, must not be neglected. On the other hand, this pandemic might bring about some of the most dramatic changes in the world of technology, especially in terms of how it is recruited in medical fields (5). Advances made in high-tech, especially in robotics and artificial intelligence (AI), have made these technologies the go-to in many industries. The COVID-19 pandemic has made the roles of these technologies even more prominent as they keep proving their efficacy in replacing humans in this pandemic (5, 6). However, this has never been the case for the healthcare industry. When it comes to human lives and health, relying on machines is not as easy as it might be with other industries. In many industries, robots have been replacing/assisting humans in tasks that are considered hazardous to humans (6). The same logic can be used to protect medical professionals during a pandemic as part of the efforts made to minimize person-to-person contact as much as possible. Therefore, this pandemic might be a chance for machines to secure their spot in the healthcare industry. Even though robotics and AI have proven their efficacy in many medical areas over the past years, their use has been a subject of reluctance, especially when performing independently of humans (7). Their use in urgent situations is a subject of debate in terms of reliability and legal issues. On the other hand, their efficacy has not been extensively investigated in major scales thus far. For these reasons, widespread implementation of these technologies in cases of emergency is not advised; however, they may be key in changing the outcome of this pandemic (8-9). Also, proving their efficacy in scales as great as a pandemic can be the key accelerator needed to secure their implementation in medicine. Herein, we overview how AI and robotics can be implemented in delivering healthcare services to non-urgent patients, lifting some of the burden of this pandemic from the shoulders of the healthcare system and allowing better management of resources.

AI in drawing the line between urgent and non-urgent cases

Before discussing how AI and robotics can serve in the management of non-urgent cases, the concept of AI deciding which case is urgent and which one is not must be discussed. In common practice, the triage system mostly draws the line between urgent and non-urgent cases. In this system, a human expert usually decides how critical an incoming case is. This task can be performed either merely based on the knowledge of the human expert or with the assistance of computers. However, increasing emergency department (ED) visits throughout the past decades has pushed forward the idea of developing AI-based clinical decision support systems (CDSS) that can make the decision of whether an incoming individual requires urgent medical care or not (10). Many of these systems implement two of the machine learning (ML) algorithms: decision trees and Bayesian networks (10). These algorithms are preferred over other ML algorithms, such as neural networks or support vector machines (SVM), as their methods of processing and learning from the provided data are understandable and, therefore, modifiable by human experts. The algorithms developed can have robust performance and appropriate accuracy even in the face of missing or redundant data and inconsistency of the information based on which the algorithms are trained. The algorithms used to assist human experts in classifying patients as urgent versus non-urgent have shown more than 90% accuracy (10). As mentioned earlier, apart from attempts to minimize person-to-person contact, one of the main goals of decreasing ED visits during the COVID-19 pandemic is the appropriate allocation of resources and preventing burnout of human resources. Therefore, it is important to develop strategies that can address these goals. Even though some attempts have been made to decrease ED visits during the COVID-19 pandemic through measures such as education on the common symptoms of COVID-19, these attempts are not appropriately integrated with AI. On the other hand, many AI algorithms have been developed to classify patients as urgent and non-urgent and are developed for settings in which patients are already present in healthcare facilities (10).

Remote triage systems through telecommunication with a primary healthcare provider have been used to replace face-to-face visits with healthcare providers (11). On the other hand, smartphones have been used to collect information in order to decide the triage level; however, these methods are mostly dependent on human intelligence rather than AI (11). A combination of these methods can be integrated with AI to allow human experts to exercise remote triage independence. Smartphone applications can be used to collect information about the patient, and then these data can be used to retrieve information using natural language processing (NLP) algorithms (10, 12). Integration of these methods with real-time global positioning system (GPS) tracking can be used to provide emergency care to patients classified as urgent (13). However, developing a triage system that performs the classification of patients outside the healthcare setting is challenging in several aspects, including legal issues, the availability of required resources (such as access to smartphones), and the pace of response to critical patients. Implementing such methods is of utmost importance as patients, due to several reasons such as access to prompt care and inability to schedule visits with primary care providers, tend to check into ED (11). Referral of non-urgent patients to appropriate outpatient settings can help allocate ED resources to urgent patients. AI and robotics, in addition to providing emergency care in many settings, such as endotracheal intubation or cardiac massage (14), can be used efficiently in nonurgent settings. As recruitment of AI and robotics is promised to change the future of medicine, virtually every field in medicine has adopted AI and robotics-based approaches in providing healthcare and performing research. Herein, some of the most prominent applications of AI and robotics that can be helpful during this pandemic are discussed.

AI and robotics to make the clinical diagnosis

The advances made in both AI and robotics make the replacement of human resources and experts in many fields of medicine possible. Perhaps the most important interaction between the physician and the patient revolves around the process of taking a history, performing a physical examination, consulting and educating patients regarding their conditions, and providing emotional support to patients. Even though improvements have been made in regard to detectors and sensors that can be used in performing a physical examination (15,16), these tasks are still challenged by many factors in some areas of medicine. For example, performing an abdominal examination is much more detailed than performing a physical examination for a skin lesion. The former needs to address various aspects, from palpation to analyzing the patient's grimace, which is not as feasible as the latter. In the example of examining a skin lesion, AI can perform efficiently, given its advancements in image processing (17).

Biopsies can be performed by robots, and the samples can be examined histopathologically using AI's image processing abilities (18). The image processing abilities of AI can be integrated or used as part of physical examination in different areas of medicine, and they can be used to diagnose many diseases. Diagnosis of ear and throat diseases (19) and fundoscopy for different purposes (20), especially in the staging of diabetic retinopathy, can be extremely helpful in minimizing the risk of contracting infectious agents such as SARS-CoV-2, given the vulnerability of diabetic patients faced with infections and a higher risk of developing serious consequences. In these examples, the integration of AI into physical examination has resulted in decisions that are as accurate as those made by human experts, if not more accurate. Therefore, relying on such advancements and technologies in the time of the pandemic and even after the pandemic is of utmost importance as they minimize the risk of contracting infectious agents for both the patient and the physician as they increase the physical distance required for making a diagnosis.

AI and robotics in diagnostic tools

As briefly mentioned earlier, one of the strength points of AI is its ability to process images. This makes it a target of interest in the field of medical imaging (21). Furthermore, robots can replace human resources in performing tasks such as providing guides and directions regarding the imaging process and emotional support to patients during the process. Many of the diagnostic procedures, such as echocardiography and sonography, can be performed by robots (22-24); however, they mostly require a human expert to control the procedure. The results obtained from these diagnostic tools can be used to be interpreted with AI, which can perform this task with greater accuracy and less error compared to human experts. Other paraclinical procedures, such as collecting blood samples for lab testing, can be performed entirely by robots, given the ability of robots to perform venipunctures and handle samples (25). They can also be used in taking a biopsy as well as interpreting the results. Furthermore, robots can be used to perform more invasive diagnostic and treatment procedures, such as endoscopy, colonoscopy, and percutaneous coronary intervention (PCI), to name a few (26-30). Considering the fact that many patients affected by COVID-19 can present with cardiac symptoms, especially due to myocarditis, which cannot be easily distinguished from acute coronary syndrome (ACS) (31-32), it is important to minimize the risk of contracting the disease on both patients and physicians. Recruiting such technologies in times such as this pandemic, despite seeming to be trivial in some instances, such as performing venipuncture, is of utmost importance as maintaining physical distance in many settings, such as the examples provided here, may not be feasible.

AI and robotics in surgery

Surgery is one of the areas of medicine severely impacted by the COVID-19 pandemic (33-34). Even though surgical services in many fields are still provided to urgent patients as they are critical to saving patients' lives, they are postponed in many non-urgent cases (35). Given the fact that many non-urgent surgical patients can become urgent swiftly, and also considering that it is not clear when the pandemic will become under control, it is not quite clear when the surgeries will be postponed. This leads to frustration of patients, and even worse, to increased morbidities and mortality of patients. For instance, in cases such as oncosurgery, physicians have been made to make the hard decision of postponing surgery or removing surgery from the protocol of treatment and offering patients medical-only treatments, which in many cases is not clear how the response of the patients to the provided treatment will be (35, 36). Considering the immune state of cancer patients, it is critical to minimize their risk of contracting the disease. Therefore, integrating robotics and AI into surgical procedures can allow performing surgeries with minimal risk of infection.

The process of preparing patients for surgery, from endotracheal intubation to performing the surgery itself, puts both the patient and the surgical team at risk of contracting infectious agents, including SARS-CoV-2. Many of the steps in this process can be performed by robots, either entirely automated or under the supervision of humans. Robots have been used for surgical purposes for more than three decades (37). Even the first robot that was used by a neurosurgeon to perform a biopsy had more accuracy than a human surgeon with years of practice (38). Ever since robots have improved even more in efficacy, their use has become more frequent in surgeries in different medical areas. They can perform these surgeries either fully automated or controlled by human experts. Of the surgical procedures robots can perform as well as, or even better than, human surgeons, stitching, excision of tumors, and localizing wounds can be named (38, 39). Thus far, much of the research on improving robotic surgery is dedicated to developing robots that can perform tedious and delicate tasks; however, given the fact that such robots can shorten the time of the surgery, they can lower the risk of disease transmission during surgical procedures. On the other hand, efforts are being made to develop robot surgeons that learn from their past mistakes, just as human surgeons do, and even more, learn from the mistakes of other robots through networks that make available access to experiences from all interconnected robots (39).

AI and robotics in dentistry

Even though the list of dental urgencies is a relatively short one, if left unattended, they can become life-threatening due to reasons such as sepsis and developing Ludwig's angina (40). On the other hand, patients may be reluctant to check in for dental care due to the nature of procedures, which is in contrast with compliance with physical distancing measures. However, recent advances in robotics have led to its approval by the Food and Drug Administration of the United States for performing some dental care procedures, such as implant placement, relatively independent from human experts (41). Robotics has also proven efficacy in other maxillofacial and aesthetic surgeries, such as cleft lip reconstruction and plastic surgeries, which, for the same reasons as dental procedures, are associated with a high risk of disease transmission (42, 43). Challenges in the way of using robotics From the beginning of the pandemic, the toll it has had on healthcare providers has been widely reflected. In almost every field of medicine, non-urgent procedures have been canceled or postponed until after the containment of the pandemic. However, this may not always be the case. Healthcare providers have faced challenges in making decisions regarding the management of at-the-time non-urgent or semi-urgent cases during the pandemic (35).

At times, they have been forced to propose alternative treatment protocols to patients, the results of which are not clear in many cases. For instance, patients with breast and colon cancer have been scheduled for chemotherapy before tumor excision rather than after its excision, for which the exact outcome is not clear (35). Other examples include modifications made in chemotherapy protocols in order to minimize the number of office visits or cancellation of clinical trials, which for cancer patients at terminal stages of life can be their only hope (35). However, in many of these instances, patients have gracefully accepted the changes made in their treatment plans and protocols in order to maintain their own safety and that of the healthcare providers. Different industries have embraced the pandemic and its consequences with different strategies, many of which are centered around remote working. However, such policies in other industries, such as medicine, require more advanced technology than providing mere telecommunication. Robotics are promising solutions to make the necessary adaptations in providing healthcare. While they may not still be reliable in cases of emergency, they can still make dramatic changes in healthcare delivery to non-urgent cases. Currently, robots meet many of the requirements in order to be widely recruited in providing healthcare, including precision, dexterity, automation, and learning. However, there are still challenges in the way of widespread and unsupervised use of these technologies in the healthcare industry (44). As an example, a challenge that may not make decisions made by AI reliable originates from the fact that these algorithms are not trained based on large, unbiased populations, and as a result, they are biased in the decisions that they make (45,46). Such biases can be resolved to a great extent once cumulative databases are used to train AI algorithms. Another challenge is the ethical and legal issues associated with the widespread use of robots in healthcare, especially when used independently of humans (47).

In medicine, especially medical interventions, unprecedented circumstances require creativity and relating to past experiences to find solutions for the challenges faced. Even though AI-driven robots can learn from past experiences and from networks of experiences gained by other robots or even humans (48), relying on their ability to make timely decisions is one of the ethical challenges, as patients' lives can be endangered. However, the learning curve for responding to such unprecedented challenges can be even shorter for robots compared to human experts, besides the fact that training robots can be much less costly than training human medical professionals (49). Furthermore, it must also be noted that factors such as anxiety and fatigue that can significantly affect the decision-making and agility of humans do not affect robots, and therefore, they may provide better results in the long run compared to human experts. Another challenge in the way of robotic medicine is the discrepancies among the countries regarding their adaptation to high-tech solutions. Therefore, the contribution of countries pioneering robotic medicine is needed in order for other countries to adopt such technologies (50). Another challenge is that many of the advancements in the field of robotics have been tested on animal models, especially those in the field of robotic surgery (35). This mandates more interdisciplinary collaboration in order to develop more advanced machines and, at times, emergency use authorization of medical devices (51). Another obstacle to the way of using robots to provide healthcare is the general public's acceptance of receiving medical care from robots. Patient-doctor interaction plays an important role in the acceptance of the proposed treatments from the patients, which can be lost by replacing human medical experts with robots. Furthermore, recruiting robots can endanger patients' privacy and impose unprecedented legal issues. **(Table 1)**

Table 1. Applications of AI Algorithms in Medicine

AI algorithm/subfield	Examples of implementation in medicine	References
Natural language processing	History taking, medical education, data mining, patient monitoring and follow-up, decision making, telemedicine	(52-54)
Naïve Bayes	Clinical diagnosis, prognosis prediction	(55)
Neural networks	Decision-making, clinical diagnosis, medical procedures	(56,57)
K-nearest neighbors	Clinical diagnosis, outcome prediction	(58)
Support vector machine	Clinical diagnosis, outcome prediction	(59)

Conclusion

The COVID-19 pandemic has changed much of what used to be considered normal. Despite being devastating in many aspects, this pandemic might be a blessing in disguise in other aspects. We can turn the threat of this pandemic into an opportunity to integrate AI and robotics into medicine more than before. Once these technologies prove their efficacy and help us out of this pandemic, the future of medicine will be changed dramatically from both educational and practical aspects. However, this requires the lag in guidelines regarding the integration of AI and robotics with medicine to be resolved. These guidelines must provide answers to some critical questions, such as whether robots can replace human experts entirely or who is accountable in case robots fail in any step of providing healthcare.

Conflict of interest

The authors declare that there is no conflict of interest.

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