Emergency response to the COVID-19 pandemic using digital health technologies: practical experience of a tertiary hospital in China

Wanmin Lian, Li Wen, Qiru Zhou, Weijie Zhu, Wenzhou Duan, Xiongzhi Xiao, Mhungu Florence, Wenchen Huang, Chongchong Li, Weibin Cheng, Junzhang Tian

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Abstract

Background: The outbreak of the novel corona virus disease (COVID-19) has caused a continuing global pandemic. Hospitals are integral in the control and prevention of COVID-19 but are met with numerous challenges in the midst of the epidemic.

Objective: The objective of our study was to introduce the practical experience of design and implementation, as well as the preliminary results, of an online COVID-19 service platform from a tertiary hospital in China.

Methods: The online COVID-19 service platform was deployed within the healthcare system of the Guangdong Second Provincial General Hospital-Internet Hospital, a program function which provides online medical services for both public individuals and lay-healthcare workers. The focal functions of this system include COVID-19 automated screening, related symptoms monitoring, online consultation, psychological support, and it also serves as a COVID-19 knowledge hub. The design and process of each functionality were introduced. The platform services usage data were collected and represented by three periods: the pre-epidemic period (2019.12.22~2020.1.22), the outbreak period (2020.1.23~2020.3.31), and the post-epidemic period (2020.4.1~2020.6.30).

Results: By the end of June 2020, the COVID-19 automated screening and symptoms monitoring system had been used by 96,642 people for 161,884 and 7,795,194 person-times. The general online consultation service volume scaled up from 930 visits per-month in pre-epidemic period to over 8406 visits during the outbreak period, and dropped to 2218 visits in the post-epidemic period. The psychological counseling program served 636 clients during epidemic period. For people who used the COVID-19 automated screening service, overall, 160,916 (99%) of the users were classified under the no risk category. Less than 464 (0.3%) of the people were categorized under the medium to high risk class, and 12 people (0.01%) were recommended for COVID-19 treatment. Among the 96,642 individuals who used the COVID-19 related symptoms monitoring service, 6,696(6.9%) were symptomatic at some points during monitoring period. Fever was the most frequently reported symptom, with 40% of the people having had this symptom. Cough (25%) and sore throat (24%) were also relatively frequently reported among the symptomatic clients.

Conclusions: The online COVID-19 service platform exhibited as a role model for using digital health technologies to respond to the COVID-19 pandemic from a tertiary hospital in China. The digital solutions of COVID-19 automated screening, daily symptoms monitoring, online care service, and knowledge propagation have plausible acceptability and feasibility for complementing offline hospital services and facilitating disease control and prevention.

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Abstract

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Methods: The online COVID-19 service platform was deployed within the healthcare system of the Guangdong Second Provincial General Hospital-Internet Hospital, a program function which provides online medical services for both public individuals and lay-healthcare workers. The focal functions of this system include COVID-19 automated screening, related symptoms monitoring, online consultation, psychological support, and it also serves as a COVID-19 knowledge hub. The design and process for each function were introduced. The platform services usage data were collected and represented by three periods: the pre-epidemic period (2019.12.22~2020.1.22, 32days), the controlled period (2020.1.23~2020.3.31, 69days), and the post-epidemic period (2020.4.1~2020.6.30, 91days).

Results: By the end of June 2020, the COVID-19 automated screening and symptoms monitoring system had been used by 96,642 people for 161,884 and 7,795,194 person-times. The number of general online consultation service per-day scaled up from 30 visits in pre-epidemic period to 122 visits during the controlled period, and dropped to 73 visits in the post-epidemic period. The psychological counseling program served 636 clients during the epidemic period. For people who used the COVID-19 automated screening service, overall, 160,916 (99.40%) of the users were classified under the no risk category. 464 (0.29%) of the people were categorized under the medium to high risk class, and 12 people (0.01%) were recommended for further COVID-19 testing and treatment. Among the 96,642 individuals who used the COVID-19 related symptoms monitoring service, 6,696 (6.9%) were symptomatic at some points during monitoring period. Fever was the most frequently reported symptom, with 2684 (40%) of the people having had this symptom. Cough and sore throat, with 1,657 (25%) and 1,622 (24%) people respectively, were also relatively frequently reported among the symptomatic clients.

Conclusions: The online COVID-19 service platform exhibited as a role model for using digital health technologies to respond to the COVID-19 pandemic from a tertiary hospital in China. The digital solutions of COVID-19 automated screening, daily symptoms monitoring, online care service, and knowledge propagation have plausible acceptability and feasibility for complementing offline hospital services and facilitating disease control and prevention.

KEYWORDS

Internet hospital; COVID-19 automated screening; symptom monitoring; online consultation; psychological support

Introduction

The occurrence of the coronavirus disease (COVID-19) has caused an ongoing global pandemic which has presently affected over 37 million people worldwide. Hospitals have been at the center of the COVID-19 control and prevention task while facing many challenges in the midst of the epidemic. The surging demands of health care for COVID-19 screening and treatment overwhelmed the medical system [1 2], and the lack of proper personal protective equipment for the medical staff caused nosocomial infection concerns [3 4]. Additionally, maintaining the routine care services such as chronic condition care and emergency outpatient visits while suspending the general outpatient visit during the epidemic, placed hospitals in discomfited states [5-7].

The Guangdong Second Provincial General Hospital (GD2H) is a large-scale tertiary hospital located in Guangzhou, China, and is renowned for its emergency medical rescue and smart hospital services. GD2H established the first Internet hospital in China in October 2014 and is one of the pioneers to explore the smart hospital [8]. By 2019, the internet hospital was upgraded with a new application which equipped with over 20 digital health technologies, including AI doctor, distance ECG diagnosis, prescription circulation platform, and medical imaging diagnosis system, etc. These digital technologies help to shift the tasks from the hospital to the community. Based on the internet hospital, GD2H has established a tiered health-care delivery system that provides professional medical care support for the lay healthcare workers in 2,377 poor villages in Guangdong, China. In the application of "5G" technology, the GD2H took the lead in carrying out the "5G" distance surgery practice in Guangdong Province. Meanwhile, as the first provincial emergency hospital in China and the 7th WHO Emergency Medical Team, GD2H was one of the major designated COVID-19 treatment centers in response to the COVID-19 outbreak in Guangdong, China.

Digital health solutions, including internet hospitals, were used to help to facilitate epidemic

control measures such as contact tracing, and pre-hospital triaging while providing online medical care have been reported [9-14]. There was a boost of internet hospital during the COVID-19 pandemic. A total of 213 new internet hospitals (compared to 362 by the end of 2019) were established between January and June 2020 in China. Over 47,000 doctors voluntarily provide medical care services in the Haodf.com (a private internet hospital platform). However, less has been documented concerning the implementation perspective of these technologies in hospitals[15]. This article introduces the practical experience of design and implementation, as well as the preliminary results, of an internet hospital-based online COVID-19 service platform, whose functions include COVID-19 automated screening, related symptoms monitoring, online care service, and additionally serves as a knowledge hub.

Materials and methods

Services Framework

The online COVID-19 platform was deployed at the GD2H Internet Hospital [8], a service which provides online medical services for both public individuals (customer client) and lay-healthcare workers (doctor client, rural healthcare personnel without formal medical training). The services framework is shown in Figure 1. The upper layer shows the service's portal, which includes WeChat (a popular social media in China, like Facebook and Twitter), smartphone App (an application developed by the GD2H), website, and target users. The main functions include COVID-19 automated screening, related symptoms monitoring, online consultation, psychological support, and COVID-19 knowledge dissemination. Modern information technologies such as internet of things, big data, and artificial intelligence, were featured in the services platform.

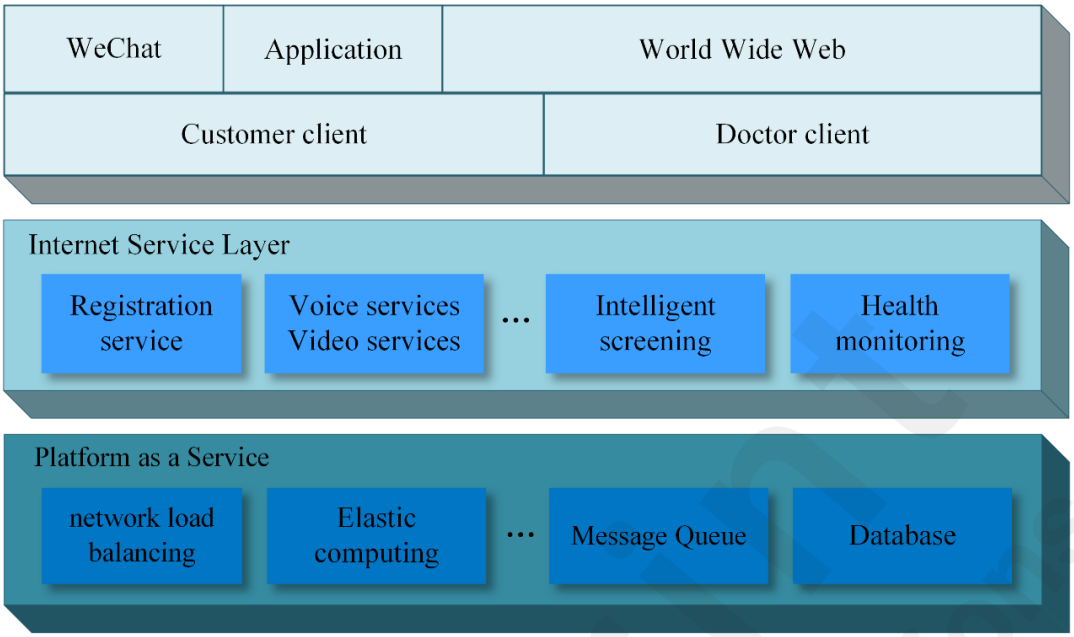

Figure 1. The internet medical services framework

COVID-19 automated screening

This service functions as a forward triage strategy that allows patients to be efficiently screened before they arrive in the hospital emergency department, which protects patients, clinicians, and the community from exposure. Automated screening algorithms were designed based on the decision tree that classified patients according to the symptoms, travel history, and exposures to COVID-19. Clients who meet the epidemiological suspected criteria then transfer to online doctors for further screening and care. Inclusion of symptoms, determination of duration and contact history are based on the COVID-19 Diagnosis and Treatment Protocol (trial version 7) issued by the National Health Commission of the People's Republic of China. Based on the report, individuals were classified as "no risk", "low risk", "Median to High risk", and "High risk". The definitions of risk category provided as appendix 1. The process of COVID-19 automated screening is shown in Figure 2.

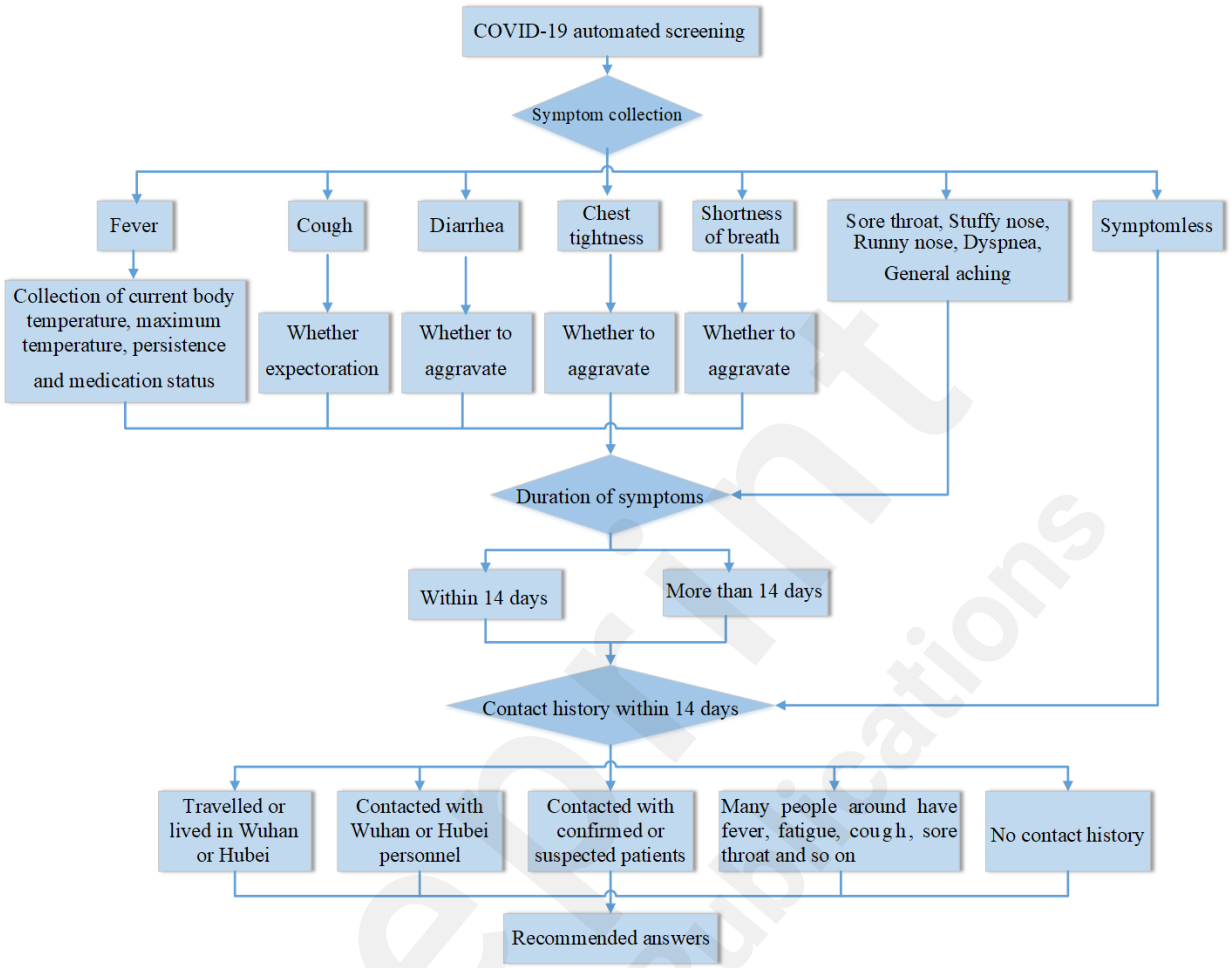

Figure 2. Flow chart for COVID-19 automated screening

COVID-19 related symptoms monitoring

This service was designed to facilitate individuals' symptoms self-management and organizations' staff health status management. Symptoms monitoring protocol was followed by the China CDC guideline for monitoring for close contact. Typical COVID-19 related symptoms, such as fever, sore throat and fatigue, were collected in a formatted way twice a day and self-reported through the App portal. A dashboard displays the visual graphics to show the changes of symptoms for users and doctors. Doctors of the internet hospital are then alerted of any abnormal statuses in a real-time manner and the internet hospital doctor then reaches out and guides the clients for risk assessment and treatment. The abnormal results which trigger the online consultation services included body temperature > = 38; body temperature > = 37.3 and sore throat; body temperature > = 37.3 and fatigue.

The process of COVID-19 related symptoms monitoring is shown in Figure 3.

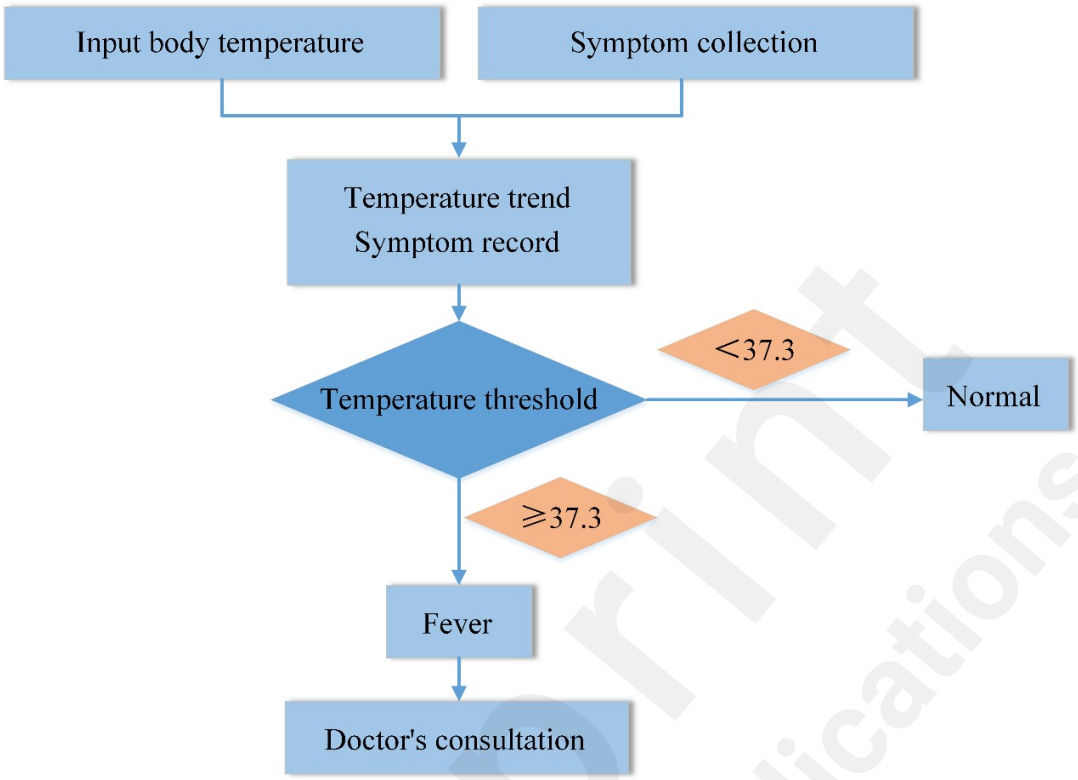

Figure 3. Flow chart for COVID-19 related symptoms monitoring

Online consultation

Online consultation provides free general medical services and psychological counseling for the public through WeChat and the App that links to the GD2H internet hospital. It also provides specialized medical care support for lay-health care workers who are met with problems while practicing medical care in their villages, and for primary care centers through a desktop system. Online consultation services can also be triggered when the results of COVID-19 automated screening or risk monitoring are abnormal.

General medical services were provided by 30 full-time professionally qualified doctors who are registered with the GD2H internet hospital. Doctors' specialties covered internal medicine, surgery, traditional Chinese medicine, and rehabilitation. Psychological counseling services were provided by licensed psychiatrists, which targeted not only the public and patients, but also medical personnel to alleviate the psychological distress caused by the epidemic.

All doctors also received professional training of COVID-19 diagnosis and treatment. Online consultation supports both text input and video consultation modes. The consultation interface allows users to upload materials including description of illness, past medical history, symptoms, test and examination results in various formats of words, pictures, sounds and images, and data uploaded by the user are encrypted to protect privacy. Doctors prescribe authenticated digital prescriptions online, which are connected to a third-party drug distribution agency that provides home delivery service for drugs. The process of COVID-19 online consultation is shown in Figure 4.

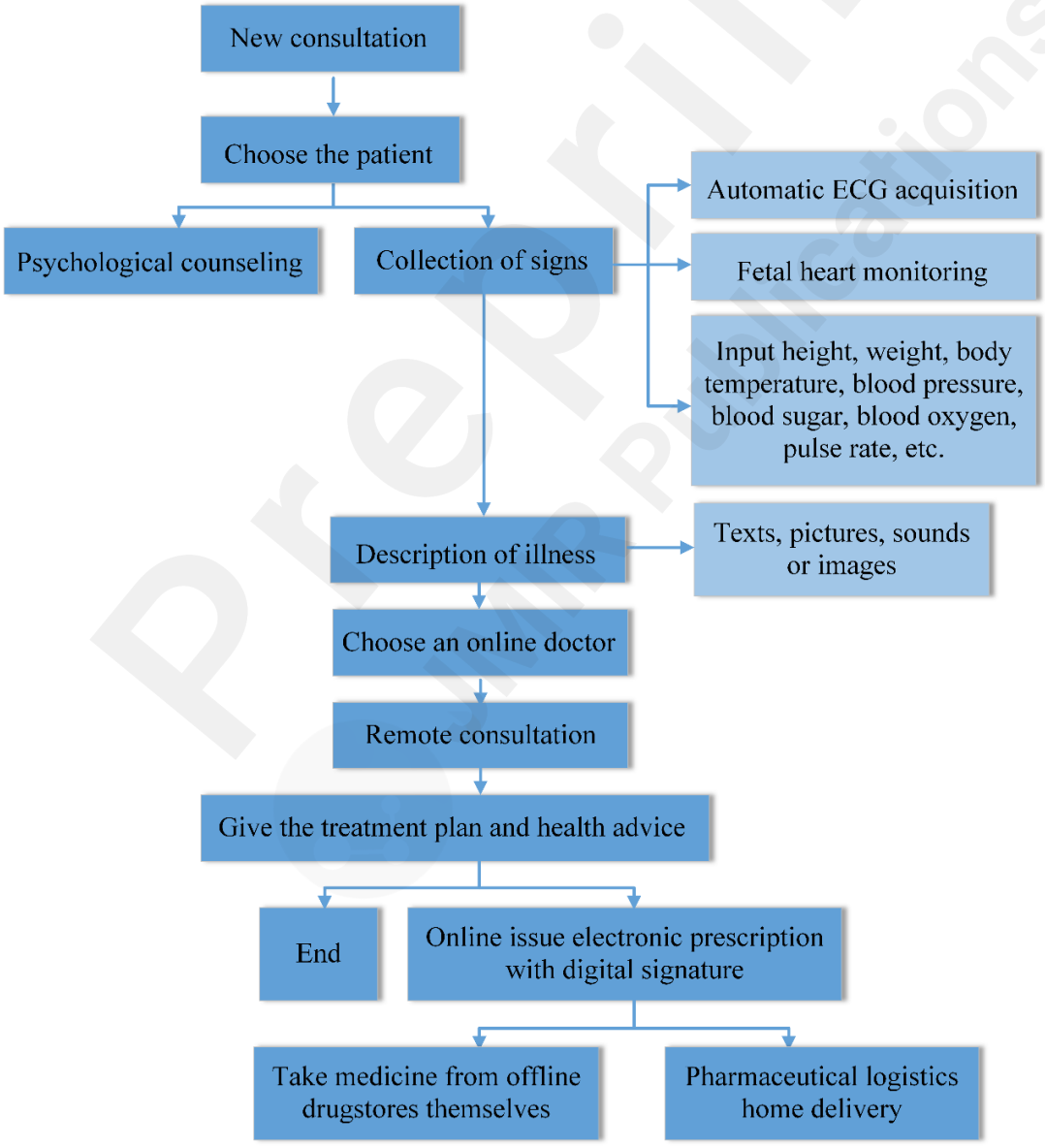

Figure 4. Flow chart for online consultation

COVID-19 Knowledge Hub

The COVID-19 knowledge hub is composed of a COVID-19 encyclopedia to educate and assist the public to understand the COVID-19 epidemic in a timely and comprehensive manner. COVID-19 related policies and prevention measures, treatment, and other information is aptly updated. The latest COVID-19 prevention and control information, such as updated guidelines and expert consensus, once officially released by the National Health Commission and the Chinese Society of Nutrition are pushed to the platform in an info-graphic form for the clients. The COVID-19 treatment module mainly provides detailed descriptions of use specifications, dosage, adverse reactions and contraindications of common antiviral drugs, immunopotentiator, glucocorticoids and antibacterial drugs. Traditional Chinese medicine, including the specific prescription composition, indications and other information, were verified through practice by the traditional medicine and sports injury rehabilitation research team of GD2H.

Data collection and analysis

The platform usage data was collected for this analysis. The COVID-19 automated screening, COVID-19 related symptoms monitoring, and online consultation services has been put into use since January 26, 2020. All data is as at June 30, 2020. January 23, 2020, is the day when Wuhan city was put on official lockdown, and the Guangdong Provincial Government declared the level one public health emergency response to COVID-19. By March 31, 2020, most of the areas in China were classified as low risk. A week later (April 8), Wuhan lifted its coronavirus restrictions, which showed the epidemic in China had been controlled. Based on these two time points, we divided the whole period into three sub-periods: pre-epidemic period (before January 23), controlled period (January 23 to March 31), and post-epidemic period (after March 31). Daily hospital services visit data (one month) were collected to compare the hospital services volume between pre and post-outbreak periods. All information was de-identified before analysis. The study was approved by the ethical review board of Guangdong Second Provincial General Hospital.

Results

The hospital outpatient visits were averagely 3,266 per day prior to the COVID-19 outbreak, then dropped to approximately 1,182 visits per-day during controlled period, and slightly increased to about 2,699 visits per-day in the post-epidemic period. While fever clinic visits increased from 11 per-day prior to the outbreak to 56 visits per-day during controlled period and 37 visits per-day in post-epidemic period (Table 1), Figure 5a shows that the outpatient visits dropped significantly early in the outbreak and ascended slowly afterwards. The trends of fever clinic visits and online consultation visits significantly increased in the early stages of the COVID-19 outbreak, then decreased to a relatively low level but still higher than the pre-epidemic period. The fever clinic visits reached the peak on March 2, 2020, 30 days after the peak of online consultation (Figure5b).

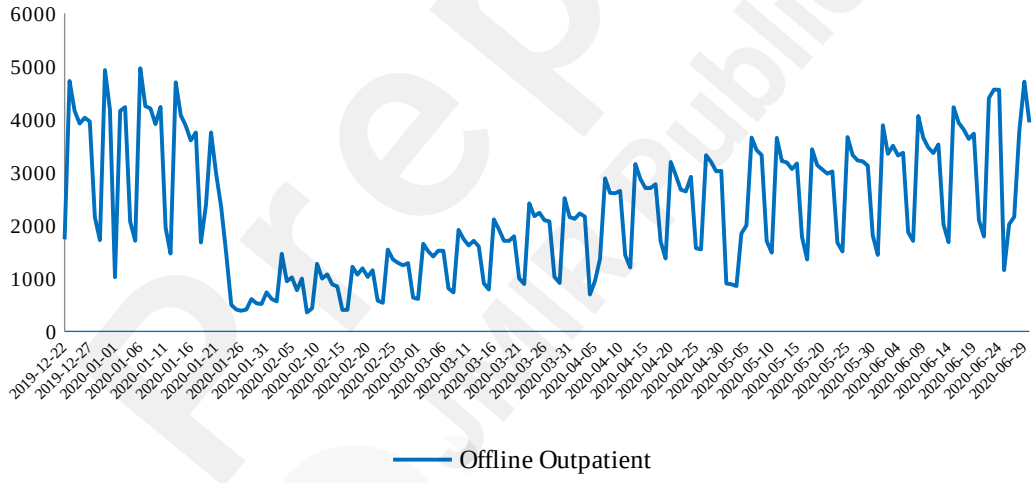

Figure 5a. The trend of hospital outpatient visits from December 22, 2019 to June 30, 2020

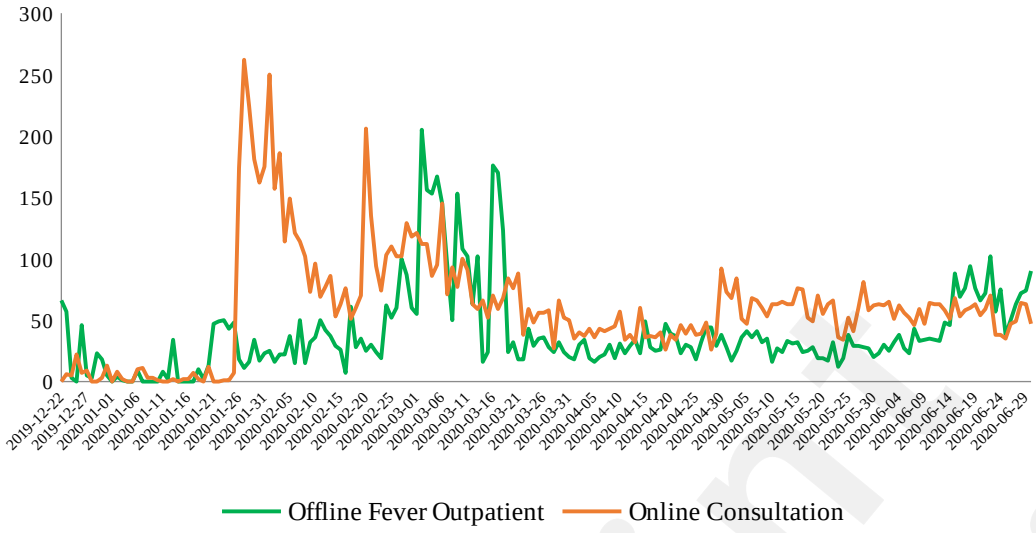

Figure 5b. The trends of fever clinic visits and online consultation visits from December 22, 2019 to June 30, 2020

The platform services usage data is shown in Table 1. By the end of June 2020, the COVID-19 automated screening and symptoms monitoring had been used by 96,642 people for 161,884 and 7,795,194 person-times. The number of general online consultation service per-day had ascended from 30 visits in the pre-epidemic period to 122 visits during the controlled period, and dropped to 73 visits in the post-epidemic period. The psychological counseling platforms served 636 clients during epidemic.

Table 1 Hospital outpatient services volume and platform services usage data by functionality in pre, during, and post epidemic periods.

	Pre-epidemic period 2019.12.22~2020.1.22 (person-times)		**Controlled period 2020.1.23~3.31** (person-times)		**Post-epidemic period 2020.4.1~6.30** (person-times)	
	Total	Per-day	Total	Per-day	Total	Per-day
Outpatient visit	104,498	3,266	81,561	1,182	245,605	2,699
Fever clinic visit	356	11	3,886	56	3,371	37
COVID-19 automated screening	-	-	93,405	1,354	68,479	752

COVID-19 related symptoms monitoring	-	-	2,006,178	29,075	5,775,357	63,465
General online Consultation	960	30	8,406	122	6,656	73
Psychological Counseling	-	-	474	7	162	2
Online prescription	830	26	1,781	26	1,898	21

For 161,884 people who had used COVID-19 automated screening service, overall, 160,916 (99.40%) of users were classified as at no risk. 464 (0.29%) of the people were classified as median to high risk, and 12 people (0.01%) were recommended for COVID-19 testing and treatment. The results of COVID-19 automated screening during controlled period and post-epidemic period are shown in Table 2.

Table 2. The results of COVID-19 automated screening during Controlled period and Post-epidemic period.

	Controlled period 2020.1.23~2020.3.31 person-times (proportion)	**Post-epidemic period 2020.4.1~2020.6.30** person-times (proportion)	**Total** person-times (proportion)
Screened	93,405 (100)	68,479 (100)	161,884 (100)
No risk	92,704 (99.25)	68,212 (99.61)	160,916 (99.40)
Low risk (home observation)	435 (0.47)	57 (0.08)	492 (0.30)
Median to High risk (quarantine)	256(0.27)	208(0.30)	464 (0.29)
High risk (treatment)	10 (0.01)	2 (0.01)	12 (0.01)

Among the 96,642 individuals who used the COVID-19 related symptoms monitoring service, 6,696(6.9%) were symptomatic at some points during monitoring. Fever was the most frequently reported symptom, where 2,684 (40%) of people reported had this symptom. Cough and sore throat, with 1,657 (25%) and 1,622 (24%) people respectively, were also recurrently reported among the symptomatic clients. The results of the COVID-19 related symptoms monitoring are shown in Table 3.

Table 3. The results of the COVID-19 related symptoms monitoring

	Controlled period 2020.1.23~2020.3.31	**Post-epidemic period**

			2020.4.1~2020.6.30	
	Number of persons (proportion)	Person-times	Number of persons (proportion)	Person-times
Normal	43,988 (94.7)	2,006,178	45,958 (91.6)	5,775,357
Symptomatic	2,468 (5.3)	5,673	4,228 (8.4)	10,343
Fever	919 (37.2)	2,666	1,765 (41.7)	5,219
Runny nose	241 (9.8)	382	468 (11.1)	766
Cough	623 (25.2)	1,111	1,036 (24.5)	1,777
Sore throat	565 (22.9)	897	1,057 (25.0)	1,605
Fatigue	399 (16.2)	617	616 (14.6)	976

Discussion

This article introduces the practical experience of application of digital health technologies in response to the COVID-19 pandemic from a public tertiary hospital perspective in China. The online COVID-19 service platform intergraded with COVID-19 automated screening, daily symptoms monitoring, online care service, and knowledge dissemination to achieve pre-hospital triage, supplement offline medical care, and facilitate disease control and prevention. Preliminary data shows that this practice has good acceptability for the public and sound applicability for complementing hospital services during an emergency crisis. Our practice can serve as a structure model for hospitals to develop their own digital health services that tailor to the technology infrastructure, disease epidemic characteristics, and the needs for the disease control.

This online COVID-19 service platform featured several functionalities that respond to the pain-points of disease epidemic [16]. COVID-19 automated screening realizes pre-hospital triage for the patients before arriving at the hospital base on epidemiological evidence of COVID-19 by using a decision tree algorithm [17]. This work substantially reduced the burden of fever clinic service and effectively evaded nosocomial infections. Additionally, daily monitoring of COVID-19 symptoms designs assisted administrative and health staff to manage links with online medical services, which guarantees the flow of work in a systematic manner. Moreover, online consultation provides medical services for individuals in a virtual setting, which supplemented the suspension of offline medical services. Psychological counseling services provide free, professional and systematic psychological

assistance to users online and offline to prevent and alleviate the psychological distress caused by the epidemic [18]. Furthermore, this online service platform overcomes time and geographical limitations, which enables people to access professional care services in a convenient way.

The platform services usage data shows that the number of online consultations sharply increased during the controlled period then slightly decreased in the post-epidemic period, while it was still far more than the pre-epidemic period. On the contrary, we established that the number of offline outpatient visits dropped significantly in the controlled period. These results suggested the applicability of using online medical services to address the challenge of maintaining medical services while reducing the chance of nosocomial infections.

Our work has several policy, implementation, and research implications. Firstly, from the policy perspective, the policymakers, based on the COVID-19 pandemic experiences, should be driven towards developing a contingency plan which contain strategies of promotion and regulation of online medical services by defining the scopes and standards, and the rights and responsibilities for the entities[19]. Secondly, from the implementation perspective, hospitals should plan ahead for the establishment of internet hospitals in accordance with local conditions, reserve digital health technologies, and formulate emergency response measures against severe infectious diseases[20]. There is no fit-for-all strategy for all hospitals, however, the functionalities should tailor to the hospital's needs and the available tools should be shared within the medical consortium to achieve the best cost-effectiveness. In addition, from the research perspective, strengthening research on online health services, including the scope of diagnosis and care of internet hospitals, acceptability for different subgroup populations, digital health solutions, and quality control measures, etc. is warranted[21].

Though the presented work has shown capabilities in preventing and fighting the COVID-19 to a certain extent, there are several ways to further strengthening the system. First, on the premise of ensuring information security, connecting the hospital's electronic medical record database and internet hospital information can provide patients with more comprehensive and reliable medical care services. Also, customizing medical services for different groups of populations such as online medical visits and home monitoring for chronic patients, can improve the efficiency of disease

diagnosis and treatment and the satisfaction of patients[6]. Of importance to note also, medical insurance payment for online medical services can further increase patients' willingness to use internet medical services.

Conclusions

The online COVID-19 service platform presented as a role model for using digital health technologies to respond to the COVID-19 pandemic from a tertiary hospital in China. The digital solutions of COVID-19 automated screening, daily symptoms monitoring, online care service, and knowledge access enablement have commendable acceptability and feasibility for complementing offline hospital services and facilitating disease control and prevention. Future studies to further evaluate the effects of relevant functions in practical applications and formulate relevant policies and measures to enhance the application of digital health technologies are of paramount importance.

Acknowledgments

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Conflict of Interest

The authors confirm that this article content has no conflicts of interest.

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Supplementary Files

Multimedia Appendixes

The definitions of risk category in COVID-19 automated screening.
URL: https://asset.jmir.pub/assets/98e1d8a6ae9d074073a85f175d651cc7.docx