



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.



## Perspective &amp; Comments

## Thinking on the informatization development of China's healthcare system in the post-COVID-19 era

Ming Zhang<sup>a,#</sup>, Danyun Dai<sup>b,#</sup>, Siliang Hou<sup>b</sup>, Wei Liu<sup>c</sup>, Feng Gao<sup>b</sup>, Dong Xu<sup>a,\*</sup>, Yu Hu<sup>a,\*</sup><sup>a</sup> President's Office, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei 430022, China<sup>b</sup> International Exchange Office, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei 430022, China<sup>c</sup> Computer Management Center, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei 430022, China

## ARTICLE INFO

## Keywords:

Coronavirus disease 2019  
Healthcare system  
Informatization

## ABSTRACT

With the application of Internet of Things, big data, cloud computing, artificial intelligence, and other cutting-edge technologies, China's medical informatization is developing rapidly. In this paper, we summarized the role of information technology in healthcare sector's battle against the Coronavirus disease 2019 (COVID-19) from the perspectives of early warning and monitoring, screening and diagnosis, medical treatment and scientific research, analyzes the bottlenecks of the development of information technology in the post-COVID-19 era, and puts forward feasible suggestions for further promoting the construction of medical informatization from the perspectives of sharing, convenience, and safety.

## 1. Introduction

In recent years, with the vigorous development of digital economy represented by "New Infrastructures", the innovation and reconstruction of healthcare industry has been emerging. Under the guidance and support of a series of national policies, the development of Internet Plus healthcare in China has come a long way. Till 2021, more than 900 Internet hospitals have been established and over 24,000 medical institutions have been carrying out telemedicine cooperation [1]. Internet of Medical Things (IoMT) plays an increasingly prominent role in optimizing medical resource allocation, innovating service mode, improving service efficiency, and reducing medical treatment cost [2]. On the basis of summarizing the role information technology played in the healthcare system during the coronavirus disease 2019 (COVID-19) outbreak, this paper discussed the problems to be solved as well as the application prospect of information technology in the healthcare system in the post-COVID era.

## 2. The role of information technology in the healthcare system during COVID-19 outbreak

In the battle against COVID-19, smart medical platforms have become the second battlefield to fight against the epidemic. Health services related to the "digital world", such as online diagnosis and treatment, science popularization for epidemic prevention, artificial intelligence,

health code and other technologies, have been fully utilized to jointly build a three-dimensional and all-round anti-epidemic protection wall to protect people's health [3-4].

In terms of early warning and monitoring, China's local governments and relevant departments used big data to study and determine the trend of epidemic, screen and track the source of infection, in order to take the initiative to control the epidemic. For example, Zhejiang province was the first to implement "one chart, one code, one index" based on big data. Mainstream media such as the People's Daily, Xinhua News Agency, and technology companies such as Alibaba and ByteDance, broadcasted the epidemic updates in real time through websites, apps and other channels, accurate to the community-level [5]. Using the big data advantages brought by real-name ticketing system, "12306" was able to provide information about close contacts. Users can confirm whether they were traveling with confirmed cases through the "Query Tool of Traveling with Confirmed Cases".

In terms of screening and diagnosis, intelligent thermometers have been used in China to quickly and accurately identify people with abnormal body temperatures in crowds. Relying on the "Artificial Intelligence plus Computed Tomography (AI + CT)" intelligent diagnostic system, a diagnosis can be made within 10 seconds by importing the patient's symptoms, epidemiological history, CT images and other data, with an accuracy rate of 98%, which greatly improves the COVID-19 screening rate and diagnostic accuracy.

\* Corresponding authors: Yu Hu, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei 430022, China; Dong Xu, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei 430022, China.

E-mail addresses: [86662373@qq.com](mailto:86662373@qq.com) (Dong Xu), [huyu\\_whuh@hust.edu.cn](mailto:huyu_whuh@hust.edu.cn) (Yu Hu).

# Ming Zhang and Danyun Dai contributed equally to this study.

In terms of medical treatment, China has launched policies such as "Notification of Providing Online Diagnosis, Treatment and Consultation Services during the Epidemic Prevention and Control" and "Guidance on Promoting 'Internet Plus' Healthcare Services during COVID-19 Prevention and Control" to encourage the medical service mode innovation, and provide online health insurance direct settlement to electronic prescription, doctor fees and expenses for medicine, which is an improvement from the policies of Internet hospitals before. Under the guidance of favorable policies, many hospitals have established Internet hospitals for the outpatient process, actively built diversified and convenient online appointment platforms, and implemented real-name appointment for medical treatment at different times [4-5]. In terms of optimizing the medical treatment process, it provides AI medical guide triage, waiting list reminder, inter-clinic settlement, mobile payment, push and mutual recognition of inspection and laboratory results, drug distribution services, etc., creating a one-stop service platform integrating consultation, prescription, payment and drug distribution [4]. According to statistics, the Internet diagnosis and treatment in the hospitals directly under the jurisdiction of National Health Commission increased by 17 times in 2020 compared with the same period last year [5]. AI, fifth generation (5G) mobile networks, Internet of Things, and remote systems are widely used in the hospitalization process. For example, Beijing Xi-aotangshan Hospital used intelligent voice medical records, makeshift hospitals in Wuhan used unmanned transport vehicles and disinfection robots, etc., Hainan People's Hospital used electronic caregiver identity cards (IDs), and some hospitals used precise infusion monitoring and 5G remote ultrasound, which all effectively reduced cross-infection and improved work efficiency. Reports from leading management consulting company, McKinsey & Co., pointed out that COVID-19 has led to rapid growth in multiple telemedicine modes, with user recognition rising to 76% from 11% in 2019.

In terms of scientific and technological breakthroughs, AI can effectively reduce the repetitive work in virus detection, and promote drug research and development through effective screening of compounds, biomarkers and prediction of physicochemical properties of drugs, etc.

In general, information technology has played an important role in alleviating patients' needs for medical treatment and improving anti-epidemic efficiency during COVID-19, demonstrating a broad prospect of a healthcare industry empowered by informatization.

### 3. Problems in the informatization of healthcare system in the post-COVID-19 era

The COVID-19 outbreak has brought huge challenges to people's health, life, and property, as well as the economic and social development. The amount of services provided by medical institutions in the healthcare industry has declined dramatically. According to the Statistical Information Center of the National Health Commission, in the first half of 2020, the total number of visits made to medical institutions recorded 3.27 billion, decreasing by 21.6% year-on-year. In the post-COVID-19 era, to speed up the resumption of efficient operation of the healthcare system, we should not only continue to optimize the demanded operations in "peacetime", but also meet the requirements of "wartime" in the new era. Through the innovative application of information technology, we can provide medical services with "no contact and few gathering". At present, although the informatization of healthcare system is booming in all parts of China, it also faces some bottlenecks in development.

#### 3.1. Regional information connectivity has not yet been realized

The sharing of health information is the foundation of online medical care and smart medical care. Especially when pandemic occurs, public health researchers, epidemiologists, and government officials need to be connected via integrated systems with connected data to understand the evolving pandemic better and make collective decisions on addressing it

[6]. Although at present, the national-level platforms have realized data sharing and exchange with the Ministry of Public Security, the Ministry of Human Resources and Social Security, the State Administration for Market Regulation, the State Taxation Administration and other ministries in China, on the micro level, there is no information interconnection among medical institutions. It is known that in 2018, the average function level of electronic medical record application in tertiary public hospitals was 2.72, which was still at the level of inter-departmental data exchange [7]. The assessment of connectivity maturity was generally around level 4, while the assessment of smart services was at level 3.

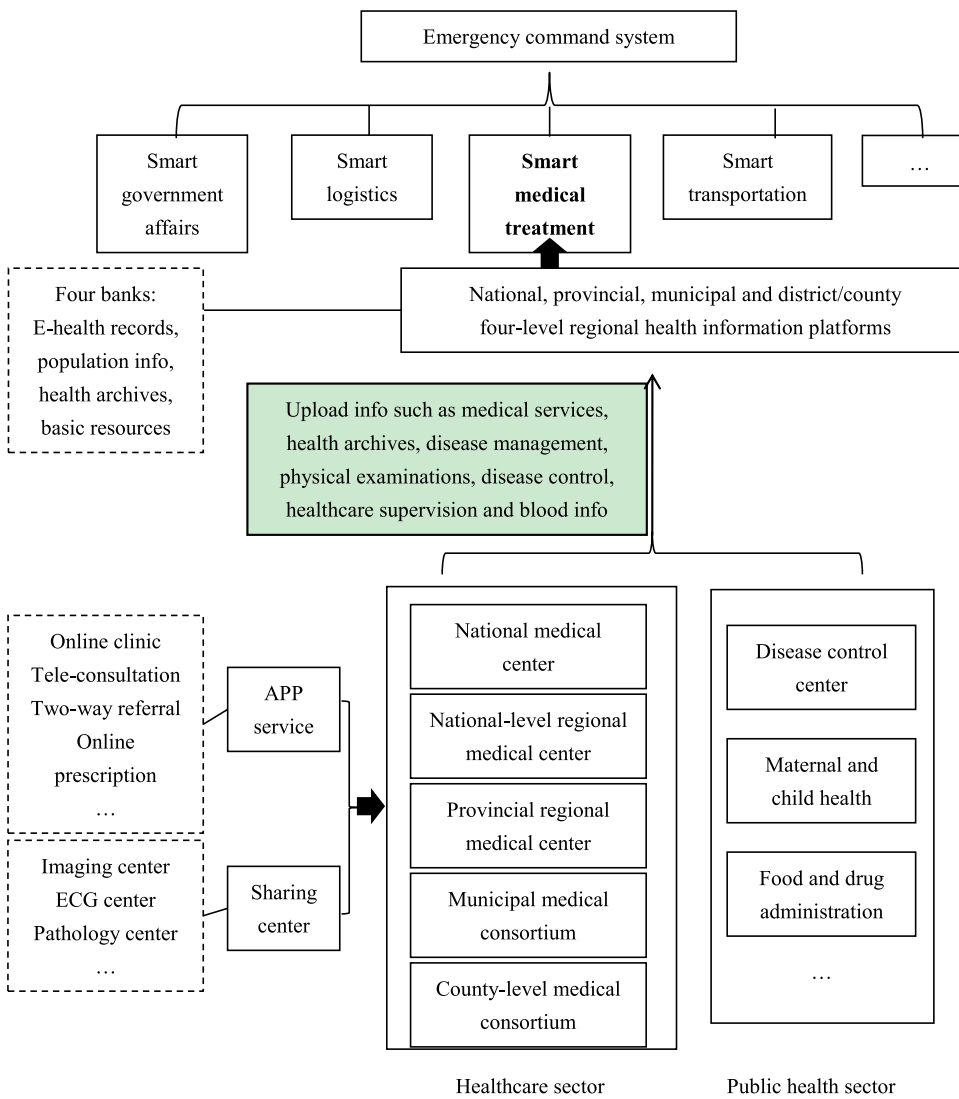
The internal data in medical institutions are mainly derived from hospital information system (HIS), picture archiving and communication systems (PACS), laboratory information management system (LIS), electronic medical record (EMR) and other application systems. For other resources of potential data, such as access control management, logistics robots, sensors and so on, they are either not developed or not utilized due to compatibility problems. Different medical institutions use different information systems, with low level of standardization, unclear ownership, right of use and management, and are difficult to connect with each other. These problems make it hard to integrate them, thus seriously hinder the informatization and intelligent development of medical services in various provinces and cities.

#### 3.2. The scope of information technology applications is limited

Medical institutions and enterprises have built online platforms for diagnosis and treatment after this public health emergency; however, the emerging information technology market needs further development. In terms of artificial intelligence, three elements for its development are data, computing power and algorithms. However, due to the lack of data quality, computing power and algorithm innovation, the popularization of artificial intelligence is affected. In terms of the Internet, the current service is limited to online follow-up, including 10 types of services such as remote monitoring, remote consultation, remote diagnosis and so on. According to the Survey Report on Hospital Information during the COVID-19 epidemic, online consultation was the most frequently used in internet hospitals during the epidemic. In addition, current supportive policies are incomplete. For example, the pricing of online services varies greatly among provinces, the examination fee is 4.5 yuan at Internet hospitals in Hubei province, and it varies from 3.6 to 15 yuan in Tianjin. In terms of the smart hospitals, though it was proposed in 2019 that the services include "smart medical care", "smart service" and "smart management", hospitals mainly provide "smart service" for patients, and need further improve other core medical services, such as closed-loop smart management of specific diseases in perioperative period.

#### 3.3. The safety of information and data need to be improved

Information in the health industry includes the citizens' personal information and the country's sensitive information, which is essential for stability of the society. Opening up medical information to the outside world increases the risks of network security regarding the rapid development of Internet Plus healthcare this year. Although online medical supervision platforms have been established at the provincial level in 30 provinces to supervise online behaviors including doctors' qualifications and their prescriptions so as to ensure the safety of medical services, medical institutions still need to strengthen data security. According to China's Medical Informatization Industry Report 2018-2019 released by the Information Management Committee of Chinese Hospital Association, 839 hospitals were surveyed with only 43.95% having passed the classified protection of cybersecurity, while 75% of primary and secondary hospitals surveyed have not implemented the classified protection of cybersecurity. In 2018, a healthcare provider in Singapore



**Fig. 1.** Structure of municipal emergency command system. E: electronic; ECG: electrocardiograph

was attacked by hackers, resulting in the release of medical records of about 1.5 million patients.

The Law of the People’s Republic of China on Basic Healthcare and Health Promotion states clearly the legal consequences of revealing the personal health information by medical institutions and healthcare personnel. But when it comes to internet-based medical services, there is no designated law or regulation on collection, use and storage, sharing, and disclosure notification of personal health information on the online health platforms. In terms of the management regulations, security management regulations for internet hospitals should be made including their access and supervision, and further guidelines for implementation should be added to the National Standard of Information Security Technology—Personal Information Security Specification to protect personal information.

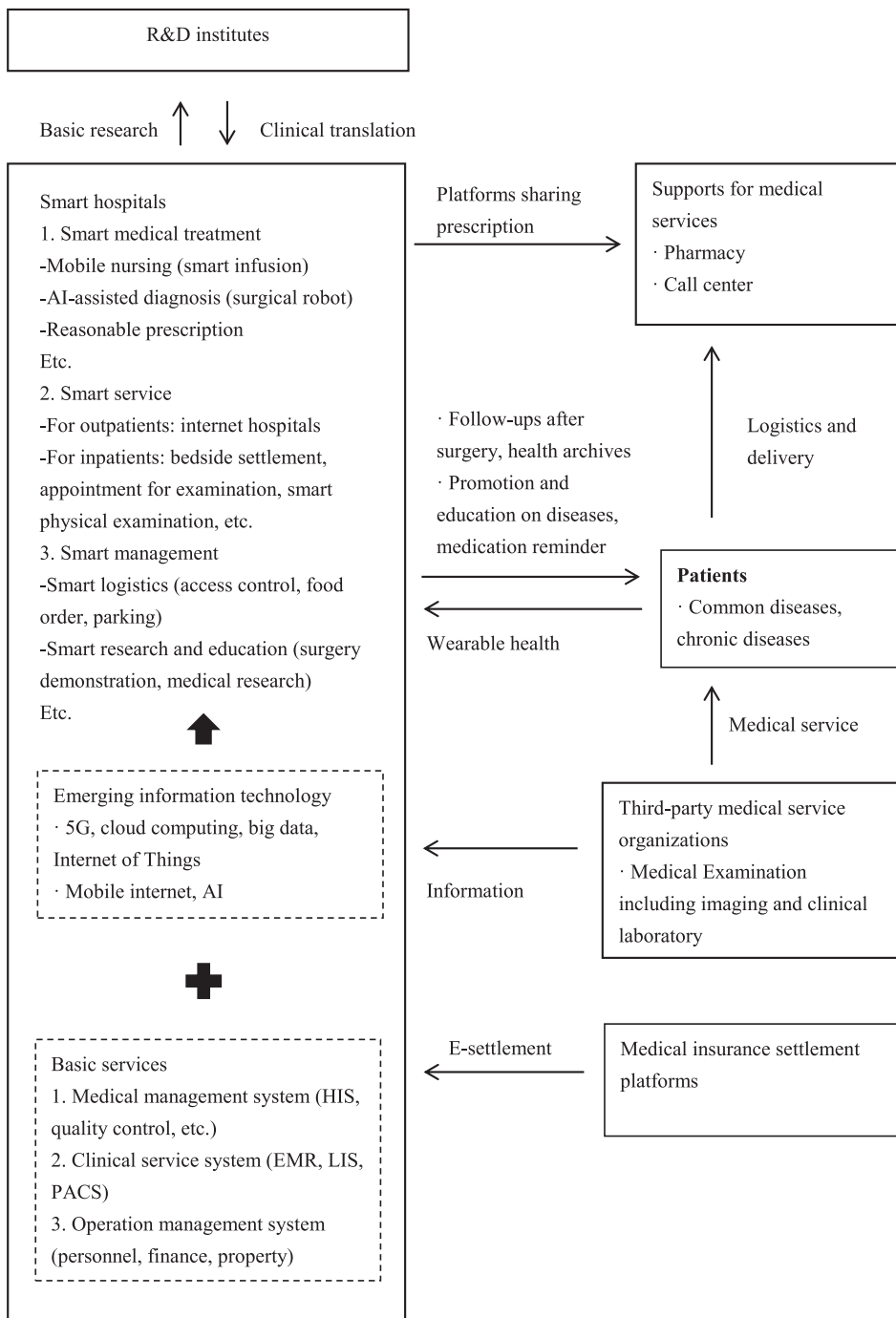
**4. Outlook on the the informatization construction of healthcare system in the post-COVID-19 era**

At present, China is in its golden age of accelerating the construction of new infrastructures, while the healthcare industry push to promote Internet Plus in medical care so that the data runs the errands instead of people. "Promoting telemedicine" is clearly proposed in the 14th Five-Year Plan (FYP) (2021-2025) for National Economic and Social Development and the Long-Range Objectives Through the Year 2035. In

the phase of regular epidemic prevention and control, the informatization construction of healthcare system will focus on the overall lifelong health of patients, and move towards a highly shared, convenient and safe direction.

*4.1. Construction of regional platforms based on information sharing*

In the past 10 years, the National Health Commission has successively issued a number of policy documents, management regulations, and standards related to regional health informatization construction. From the perspective of governance of a city, smart medical services should be integrated into the construction of smart city by means of top-level design and overall planning, and connected with emergency command system, smart transportation and smart government. Once a major public health emergency occurs, the smart medical system will start the early warning system according to the intelligent algorithm, and the emergency command center will respond with an emergency plan according to the level of emergency predicted by the early warning system, and establish a scientific decision-making model to control the spread of epidemic (Fig. 1). From the perspective of healthcare industry, normative data standards should be defined, compatible information system management software should be installed, and a network system supporting health informatization within a region, based on the interconnection of national, provincial, municipal and district/county



**Fig. 2.** Platform integrating "medical-patient-drug-insurance" information. R&D: research and development; AI: artificial intelligence; 5G: fifth generation; HIS: hospital information system; EMR: electronic medical record; LIS: laboratory information management system; PACS: picture archiving and communication systems

platforms, should be established as soon as possible to ensure the compatibility and sharing of data within the region. Meanwhile, coordinated development of medical institutions within a region should be oriented according to the guideline of national policies, and sharing of medical information within a region should be realized based on the construction of medical consortium so as to expand quality resources.

**4.2. Construction of closed-loop platforms based on convenience and efficiency**

At the national level, it is suggested to increase supportive policies around the integration of "medical-patient-drug-insurance" information. For example, we should further improve the scope and tiered pricing of online services in various provinces, and explore the estab-

lishment of a national or provincial platform sharing and circulating electronic prescriptions by internet hospitals and a uniform platform for medical insurance settlement. As for medical institutions, it is suggested to promote smart hospital construction by providing medical services centered on overall lifelong health of patients and integrating online and offline services before, during and after diagnosis. Smart services should extend from medical consultation to a whole process of services for common diseases and chronic diseases. Smart management should rebuild an online process of diagnosis and treatment like a physical hospital and even provide further medical services (Fig. 2). A medical ecosystem integrating producing, teaching, and researching by hospitals, suppliers, logistics, third-party medical service organizations, research and development (R&D) institutes will be gradually formed.

### 4.3. Construction of whole-process platforms based on security

At the national level, it is suggested to improve policies and regulations, establish industry standards, and enrich the content of provincial information supervision platforms. At the hospital level, it is suggested to strengthen information security management and optimize technical means, improve management regulations for information system security and doctor-patient information security. Moreover, it is suggested to build information security system and a closed-loop safety workflow of threat prediction, threat protection, continuous monitoring, response and disposal, including (1) risk pre-control: software should be selected in accordance with ISO27034 standard and safety principles, hardware should be strengthened through update and maintenance; (2) risk monitoring and control: safety of hardware/software devices and network environment should be comprehensively monitored, monitoring and early warning system for online information security should be established and improved; (3) defense construction: protection of internet-based medical information security should be strengthened by applying anti-virus software, intrusion detection system, vulnerability scanning system, data encryption technology, data desensitization technology and other technical means [8]; (4) emergency support: emergency plans and measures should be formulated and specified regarding hardware system, software system, machine room environment, information security management, etc., and emergency drill should be regularly carried out. At the individual level, it is suggested to establish the privacy protection awareness of medical staff and patients through various forms such as training, popularization and education.

### 5. In summary

In general, digital technologies such as Internet and big data have been proven to be indispensable in response to COVID-19 and become the core force for the comprehensive breakthrough and development of the healthcare industry in the post-COVID-19 era. The next step is to further carry out technology research and development and continuous improvement around key areas such as smart medical treatment, big

data mining, information sharing, family health and medical information security. Meanwhile, increased financial investment and training of "5G medical" inter-disciplinary talents are proposed to ensure stability and sustainability and to contribute to the construction of a healthy China.

### Conflicts of interest statement

The authors declare that they have no conflicts of interest.

### Funding

This study was funded by Scientific and Research Project of Health Commission of Hubei Province (Grant No: WJ2019D004).

### References

- [1] National Health Commission of the People's Republic of China Press conference about the health development in the 13<sup>th</sup> five-year by the state council information office; 2020. Available from: <http://www.nhc.gov.cn/xwzb/webcontroller.do?titleSeq=11347&gectype=1>.
- [2] Al-Turjman F, Nawaz MH, Ullas UD. Intelligence in the Internet of Medical Things era: a systematic review of current and future trends. *Comput Commun* 2019;150:644–60. doi:10.1016/j.comcom.2019.12.030.
- [3] Javaid M, Khan IH. Internet of Things (IoT) enabled healthcare helps to take the challenges of COVID-19 Pandemic. *J Oral Biol Craniofac Res* 2021;11(2):209–14. doi:10.1016/j.jobcr.2021.01.015.
- [4] Sun S, Xie Z, Yu K, et al. COVID-19 and healthcare system in China: challenges and progression for a sustainable future. *Global Health* 2021;17(1):14. doi:10.1186/s12992-021-00665-9.
- [5] Wu J, Xie X, Yang L, et al. Mobile health technology combats COVID-19 in China. *J Infect* 2021;82(1):159–98. doi:10.1016/j.jinf.2020.07.024.
- [6] He W, Zhang ZJ, Li W. Information technology solutions, challenges, and suggestions for tackling the COVID-19 pandemic. *Int J Inf Manage* 2021;57:102287. doi:10.1016/j.ijinfomgt.2020.102287.
- [7] National Health Commission of the People's Republic of China Notification on the 2018 national monitoring and analysis of the performance evaluation of tertiary public hospitals; 2020. Available from: <http://www.nhc.gov.cn/yzygj/s3593g/202006/863717ce64af4372a737048cf500eb3d.shtml>.
- [8] He Y, Camacho RS, Soygazi H, et al. Attacking and defence pathways for Intelligent Medical Diagnosis System (IMDS). *Int J Med Inform* 2021;148:104415. doi:10.1016/j.ijmedinf.2021.104415.