



Prospect and application of Internet of Things technology for prevention of SARIs



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ABSTRACT

The Internet of Things (IoT) includes three core procedures: full spectrum perception, reliable transmission, and intelligent processing. It can be applied for the prevention and control of SARI (severe acute respiratory infection). By combining sensors, information technology, artificial intelligence, and available dynamic networking devices, IoT could realize long-distance communication between hospitals, patients, and medical devices, which could ultimately improve current medical conditions.

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The new 2019 coronavirus, which is known as “2019-nCoV” (nCoV),¹ was discovered in cases of viral pneumonia in Wuhan and was named by the World Health Organization on January 12, 2020. The coronavirus is a large family of viruses known to cause influenza as well as other serious diseases such as Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS). The virus is a new strain of coronavirus that has not been found previously in humans (Fig. 1).^{2–4}

Since December 2019, Wuhan has continued to perform influenza and related disease surveillance and has reported a number of cases of viral pneumonia.⁵ The incidence rate has increased rapidly; it has exceeded 24,324 cases by Feb 4, 2020, resulting in an enormous burden on prevention and control efforts.

The common respiratory symptoms of this infection are fever, cough, and breathing difficulties. In more severe cases, pneumonia, SARS, kidney failure, and even death can occur. Currently, there is no specific treatment against the new coronaviruses. Supportive therapy is the primary treatment for this disease and for preventing complications.²

There have been a considerable number of medical teams supporting Wuhan. In addition, numerous cases or virus carriers have been reported in places outside of Wuhan. This has compounded the difficulties in preventing and treating nCoV pneumonia, such as (1) efficiently learning the updated interim guideline; suggest

rapid learning interim and revised management guideline; (2) better managing suspected cases; (3) performing a consultation on difficult diagnose patients to improve the success rate of supportive treatment, and (4) directing and ensuring quality control for clinical practice. The Internet of Things (IoT) technology can be employed to achieve these goals.

History of the Internet of Things and Medical Internet of Things

Based on advanced information technology (IT) and electronic medicine, the Medical IoT (mIoT) has experienced four major evolutions, including the development of wireless sensing technology, use of Internet technology in clinical medicine, use of radio frequency identification (RFID), and artificial intelligence (AI) applications, to realize the IoT medical model.

Wireless sensing technology was first used in fetal electrocardiograms,⁶ and the use of wireless sensing technology to monitor the breathing status of patients dates back to the 1970s. Pope et al.⁷ used a temperature sensor at the head end of a tracheotomy to send a patient's breathing parameters to a signal receiver in real time through an FM transmitter. The new technology was then used in the intensive care unit (ICU) to monitor newborns and children, and assist health care workers identify apnea in a timely manner. Wireless stethoscopes designed for anesthesiologists to listen to a patient's heart rate and breathing sounds during surgery have also been developed.⁸ Wireless storage technology has since been developed to digitally record physiological parameters such

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Fig. 1. The new strain of coronavirus isolated from Chinese Center for Disease Control and Prevention.

as heart rate, breathing rate, electrocardiogram, body temperature, and blood pressure.⁹ With the development of technology, physiological parameter recorders based on wireless sensing technology are being introduced to the medical field, such as esophagus pH,¹⁰ pulse blood volume,¹¹ CO₂ decompression,¹² and wireless breathing frequency monitors during movement.¹³ Moreover, with the development of microelectronics and integrated industrial technology, numerous sensing technologies have been developed, such as the “smart T-shirt”.^{14,15} The concept of instant “plug and play” modular installation has further accelerated the development of the “sensor network,” which can be easily applied for heart, lung function, and other joint monitoring.

Clinical application of the Internet

In 2001, for the first time, Gandsas and Montgomery¹⁶ in the United States, using the wireless application protocol (WAP), connected to a laptop using the Internet to obtain telemedicine data including blood pressure, pulse, breathing frequency, moisture, oxygen saturation, and electrocardiograms, in “anytime and anywhere.” This technology was mainly implemented through the cell digital packet data (CDPD) of digital cell phones to achieve high-speed transmission of data, anytime and anywhere (up to 19,200 bps). In the 21st century, with the combination of wireless sensors and Internet technology, clinicians have been able to apply this convenient and more accurate measurement technology for the observation and prevention of disease. For example, in a high-risk population with congestive heart failure, the use of a wireless cardiopulmonary monitoring system can discover early signs of Chen-Shi breathing.¹⁷

RFID-based IoT medical model

In the IoT industry chain, RFID is one of the core technologies for item identification. It applies a radio frequent spatial coupling signal (among magnetic or electromagnetic fields) to achieve wireless information transmission and for identification purposes. RFID was first used in the field of supply chain management; it is now also used in the medical industry. In 2004, Virtua Medical¹⁸ installed RFID systems in four hospitals to track and manage thousands of patients and staff, as well as 10,000 assets. Two years later, a clinical trial¹⁹ was conducted in New Jersey, USA, using an implantable RFID microtag. Physicians could view chronic disease information from an implanted VeriChip in the patients’ upper arm.

Application of Medical Internet of Things in respiratory disease management

Advances in wireless sensing and IT have also laid the foundation for the use of the mIoT in respiratory disorders. In the field of the monitoring of respiratory physiology, the application and development of wireless sensing technology is particularly prominent. The types of sensors include: (1) abdominal band-type: indirect determination of moisture volume²⁰; (2) inductance plethysmograph method¹⁵; (3) video monitoring system²¹; and (4) radio detector: measuring chest motion.²² These innovations have also led to the application of the mIoT to sleep medicine. In 2012, the Zhongshan Hospital Fudan University and Shanghai Respiratory Research Institute established the first sleep center medical model, the “Cloud Plus Terminal Medical Internet of Things Sleep Laboratory,” which interacts with five district and community hospitals on the platform. The application of Cloud Plus Terminal Medical Internet of Things facilitates the early diagnosis and management of sleep respiratory disorders. Using this new healthcare model, patients can visit a community hospital, and yet receive high-quality healthcare service from the Zhongshan Hospital. This reduces the problem of overcrowding in large hospitals and assists community physicians to resolve the challenges inherent to the diagnosis and management of difficult cases. It realizes the prospect of “The experts are linked by the cloud—The public enjoys modern medical treatment.” For example, a successful wireless sensing pulmonary function meter has been developed at Zhongshan Hospital Fudan University, by which patients can complete lung function monitoring from home.^{23,24} Physicians can view the patient’s lung function changes and recommend treatment based on the data, simultaneously, online, and propose a three-level linkage of mIoT models. On October 25, 2019, the Chinese Alliance Against Lung Cancer established the AI Committee for the Early Diagnosis and Treatment of Lung Cancer. The objective of this new committee is to certify and further train well educated physicians to apply AI in the early diagnosis of lung cancer.

Potential value of Internet of Things-assisted prevention of SARI

As mentioned above, the incidence of SARIs is increasing rapidly, which imposes an enormous burden on prevention and treatment. There have been numerous cases of SARIs and instances of individuals carrying the virus exporting it to other places, which makes prevention and treatment more difficult. At present, there are a number of medical teams available to support Wuhan. However, it may be possible to significantly improve the efforts of these medical teams by employing IoT technology. The IoT is an important part of the next generation of IT. The core of the IoT is a network that extends and expands based on the Internet; the user side can be extended, thereby improving information exchange and communication among the “things.” mIoT is the science of intelligent identification, location, monitoring, and AI services for SARI patients using RFID, Global Positioning Systems, different sensing devices, information exchange, and communication according to an agreed arrangement. If we can delve deeper into its function, it can undoubtedly yield unexpected results.

Medical Internet of Things auxiliary hospitals and drug management

In the clinical work of preventing SARIs, RFID readers can be installed on robots, and UHF stickers can be read when a drug is uploaded to the robot to confirm drug distribution. This clinical application has gained relevant experience.^{18,19} Once a robot

activates its RFID reader, it can obtain the appropriate information and quantity of all the drugs in a drawer, and through the precise matching of the drug information, a drug can be sent to the SARI medical units correctly. The Geisinger Medical Center in Danville, Pennsylvania, USA, has adopted embedded RFID robots to ensure that a drug is actually delivered to all units of use, with images transmitted instantly. It is hoped that Wuhan's two mountain infectious disease hospitals can also be equipped with similar equipment to achieve the corresponding services. RFID technology can also be used to build a medical waste management system, which can easily monitor and track the entire SARI medical waste process including generation, recycling, transportation, and treatment.

Auxiliary quick learning and implementing guideline

There are already a number of medical teams to support Wuhan. However, it is necessary to elucidate methods of faster learning and providing high-quality implementation interim guidance. In the management of lung nodules, we have gained extensive experience to prove that augmented reality (AR) technology based on the IoT 5A process is a technology that integrates virtual information with the real world. It uses a variety of technical means including multimedia, 3D modeling, real-time tracking and registration, intelligent interaction, and sensing to simulate computer-generated text, images, 3D models, music, video, and other virtual information, and apply these to the real world. Can play to the current level of different levels of the handicraft workshop-style diagnosis and treatment model upgraded to the national, and even international standards of modern flow ingesting works.^{25,26} This experience could also be easily applied to assisting SARI prevention and control. We could incorporate the key points of the interim guidance into the 5A process, adding quality control to ensure that they are performed with high quality. Will have a concise, easy-to-promote and universal effect.

Auxiliary consultation to improve successful rescue rate

SARI is reported to have a high incidence with a staggering number of deaths. Causes of death are related to sepsis, hypoxic respiratory failure, acute respiratory distress syndrome (ARDS), multiple organ failure, and complications and pregnancy. If these complications can be addressed in a timely manner, early support for treatment and monitoring, and immediate oxygenation therapy for patients with respiratory distress, hypoxemia, or shock can undoubtedly reduce mortality. However, the large number of doctors participating in the rescue work, many with no corresponding experience, require the guidance of experienced experts; however, experienced experts are extremely limited. The IoT can assist in this task. With AR technology, experts and front-line physicians can perform and support consultations through AR, which can be easily and quickly completed without time, space, and location constraints, while reducing the probability of infection and avoiding the requirement of isolation after consultation.

Improving the level of management for suspected patients

The management of suspected patients is a difficult problem. The reason is that at present, only patients with fever or those who have become ill can be identified. The numerous possible carriers of the virus are not isolated and become the next generation of infection. Ask them stay in their own homes or stay in community to reduce personal transmission. The guidelines suggest self-protection including maintaining basic hand and respiratory hygiene, maintaining safe eating habits, and avoiding close contact with anyone who exhibits symptoms of respiratory diseases (such

as coughing and sneezing). However, the effect of the execution of this guideline is not known and there is no quality control. Hence, there is an urgent requirement to apply the IoT to assist in the management of this group of patients. Compared with traditional medicine, mIoT can monitor the physiological and pathological state of the suspected patients throughout the process, reflecting the management advantages including providing personalized health solutions for different groups of people. Through the use of wireless sensor equipment and modern IT, patients can enjoy professional services, thereby ensuring the safety of suspected patients and also avoiding the infection of their families.

Assist in quality control

During a period when the SARI incidence rate is high, requiring the participation of the co-working hospitals and numerous doctors, it is challenging to ensure the quality of medical care. This is an unavoidable challenge. To complete the diagnosis and treatment of SARIs efficiently and accurately, while ensuring security, it is necessary to precisely coordinate the division of labor between the hospitals and physicians at all levels of the mIoT. Clinical quality control based on the Internet of Things lies in the application of the inherent advantages of the three basic processes of the Internet of Things identified above, while utilizing its ten basic functions, real-time, transparent and efficient quality control of the Medical Internet of Things classification. The original data on the patient side and the medical information processed by the cloud computer in the five-step method can be stored in a seamless link, real-time online form in the vast space of the medical center's cloud server. Automatic grading mode with the default setting. In addition to the intelligent management of the classification model of disease risk, it is easy to process and classify large amounts of information. Moreover, through high-speed information quality monitoring and a professional epidemiological data statistics model, we can effectively obtain the results of the most current quality control, efficiently monitor and provide an early warning of potential risks, and feedback to hospitals and physicians at all levels, in a timely fashion, the formation of the three-level linkage of corrective programs, ultimately achieving patient and social satisfaction.

Development direction and prospect of Medical Internet of Things

The current mIoT is not mature; there are numerous urgent problems to be resolved. However, it is expected to contribute considerably to the prevention and treatment of SARIs. This technology completely complies with the national control of diseases, the "prevention and control of the forward, focus on sinking" requirements. The issues related to "borrowing" the IoT technology are: (1) faster leaning and ensuring a high-quality implementation guideline; (2) better managing suspected patients; (3) effectively dealing with difficult patient consultations and improving the success rate of rescue; and (4) commanding and ensuring effective quality control. Moreover, the development and diffusion of the mIoT must address the following unresolved issues: (1) improve interoperability: the adoption of open standards must ensure that products from different manufacturers can communicate with each other; (2) ensure that there is no leakage; and (3) enhance the distribution network: sensors must communicate with services such as the Internet and wireless networks such that information can be relayed to remote health workers.²⁷

To solve these problems, there is an urgent requirement to develop a modern medical model – mIoT and to use this to improve the current telemedicine, coupled with mobile phones and other popular user terminals. This should be more conducive

to achieving: “easy to prevent, easy to diagnose, easy to treat diseases, and to easily communicate with experienced doctors.” Community physicians can be advised in real-time by medical center experts through the cloud-plus terminal mIoT technology to achieve early diagnosis and optimal co-management of SARI patients.

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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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