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https://doi.org/10.15017/4400022

出版情報：決断科学. 8, pp.53-64, 2021-03-23. Institute of Decision Science for a Sustainable Society, Kyushu University
バージョン：
権利関係：

Research Note（Non-Peer Reviewed Paper）（研究ノート）

The history, applications of telemedicine and prospects for COVID-19 triage

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Abstract:

Telemedicine is the distribution of health-related services and information via electronic information and telecommunication technologies, mainly including long-distance patient and clinician contact, care, advice, reminders, education, intervention, monitoring, and remote admissions. In recent years, with the development of telemedicine in various stages of medical care, the role of telemedicine is increasingly recognized. In 2020, the outbreak of COVID-19 has greatly impacted the traditional medical service model, but at the same time, brings opportunities to telemedicine development. In this article, we reviewed the history of telemedicine, different forms and applications of telemedicine and prospected the role of telemedicine in the fight against COVID-19, especially in the triage system.

1. History of telemedicine

Telemedicine system originated from developments of telecommunications. As early as Civil War, telegraph was used to transmit medical information, such as order medical supplies and casualty lists [1], which is considered to be the early prototype of telemedicine. Around the 1950s, with the development of telecom technologies, attempts of telemedicine was made in some hospital-led projects. in the 1950s, Canadian radiologists at Montreal's Jean-Talon Hospital created a teleradiology system to transport radiologic images by telephone, one view is that this is the first recorded utilization of telemedicine [2]. In the 1960s, the development of telemedicine was largely promoted by two major events. the introduction of television and space-flight program in USA [3]. By the late of 1950s, developments in closed-circuit television and video telecommunications were recognized by medical personnel, In 1959, clinicians at the University of Nebraska used two-way interactive television to transmit information

about neurological examinations [4]. In 1964, a telemedicine link between Nebraska Psychiatric Institute and the Norfolk State Hospital (112 miles away) was established to provide speech therapy, neurological examinations, group therapy consultations and educational train [2]. Although the doctors have taken advantages of the communication transmission at that time, limited by technical problems , telemedicine still stayed at the stage of information exchange. At the same time, the intervention of National Aeronautics and Space Administration (NASA) greatly promoted the development of telemedicine from the other side. In manned space-flight programs, the physiological functions for astronauts in space need to be real-time monitored by physicians on earth. In this project, NASA's scientists developed sophisticated biomedical telemetry and telecommunications systems for biomedical applications [5]. Space environment, especially the absence of gravity was firstly concerned may impede circulation, respiration, and digestion, so the early monitoring focused on physiological indications of circulatory and respiratory systems. As the space program moves forward, the telemedicine was extended to information transmission for X rays detection, medical records, and laboratory data.

Although the original research was intended to serve space program, with the end of the Apollo program and the subsequent funding cuts for human spaceflight programs, people have to consider other ways to use telemedicine technologies. A new program which called Space Technology Applied to Rural Papago Advanced Health Care (STARPAHC) was emerged in this context. Medical care was provided to Native Americans on the Papago Reservation in Arizona via telemedicine. The program was thought to be pioneering a model of medical services for remote areas, spurred subsequent researches of medical engineering, leading to quick growth for telemedicine [6].

2. Different forms and applications of telemedicine

From Manned spaceflight to medical services for remote areas, there has been a shift in the direction of telemedicine services. However, with the continuous development of medical technology and communication technology, telemedicine has shown considerable application potential in a variety of directions.

A tool for specific clinical-care

Until the 1990s, multiple clinical-care applications of telemedicine have been reported, such as the applications in anesthesia, dermatology, cardiology, psychiatry, radiology, critical care, and oncology [7]. In recent years, the use of telemedicine in intensive care unit (ICU) was also taken seriously.

ICU is generally considered to be staffed by highly trained physicians, nurses and respiratory therapists, and also distinguished from general hospital wards by a higher staff-to-patient ratio. However, many patients lack access to this level of care, particularly in small hospitals and in rural areas. Base on this, telemedicine could be a tool to connect different levels of medical institutions by delivering the knowledge and experience from intensive care specialists to the hospitals with inadequate access to intensive care specialists [8]. Recent reports have confirmed the value of telemedicine for ICU to improve core clinical outcomes for ICU patients, reduce in-hospital mortality [9], and increase financial performance of hospitals [10].

A Tool for cross-regional medical cooperation.

Cross-border medical cooperation via telemedicine has always been a hot topic. In addition to the differences in medical level and medical resource, differences in geographical location, living habits, and genetic distribution between countries also led to different experience dealing with diseases. The early cross-border telemedicine services were focused on communica-

tion between medical experts, share the rare cases, solve intractable diseases, or provide guidance for difficult operations.

Eu countries have the advantage of being geographically close to each other, it makes regional cooperation easier. In 2004, the European Commission presented an action plan for a European e-Health Area [11]. After a few years of development, current E-Health program comprises the application directions such as : clinical information sharing systems; home care or personalized health services for remote patients; and secondary usage of non-clinical systems, such as the specialized systems for researchers, or support systems [12].

By 2020, the electronic cross-border health services such as "ePrescription" and "Patient Summaries" has been gradually provided among EU member states, EU citizens could obtain their medication in a pharmacy located in another EU country; and a doctor could get patient's information such as allergies, current medication, previous illness, surgeries via this program.

In 2002, Korea and Japan co-hosted the Football World Cup, a large fiber-optic network was built for race signals transmission. As a result, many fields, including health care, realized cross-regional telecommunication. With support from the government programs, a medical team from Kyushu university, Fukuoka, led the establishment of "Asia-Kyushu Advanced Medical Network (AQUA)" in 2005, and rapidly developed cooperation with neighboring countries [13]. In 2008, A new office which was called Telemedicine Development Center of Asia (TEMDEC) was opened to further promote consistent medical communications among Asian countries. Different from Europe, which focuses on the information base in telemedicine, TEMDEC could provide more real-time communication, also the detailed picture and high-quality video data via the super-fast Internet and advanced technology.

Current Asia telemedicine project has already covered many countries

and facilities in the world, mainly focus on remote medical education; remote patient care; international medical doctors experience exchange and education program; development and application of new technology for network connections and better images.

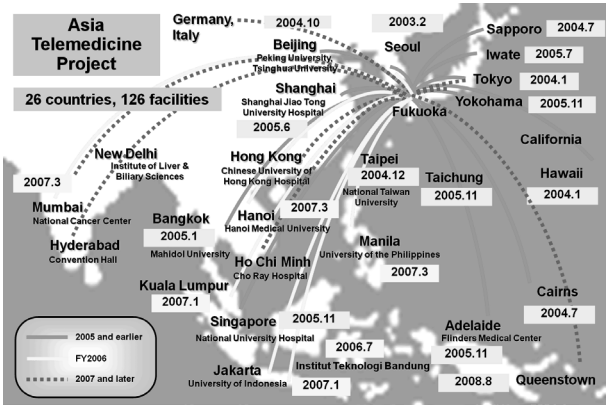

Figure 1. Asia telemedicine project [14].

A Tool for medical support to remote areas

Return to one of the original applications of telemedicine, many countries attach great importance to the application of telemedicine in remote areas. Usually, small villages or sparsely-populated areas have one doctor or nurse for all kinds of problems who cannot turn to anyone for advice. Although some countries tried to solve this problem by training general practitioners, the cost of time and money is still unsustainable. Within this context, telemedicine can become a bridge between superior hospitals and primary medical service institutions, even directly to patients. And overall, it can balance out inequalities in care services that present when it comes to

remote communities and densely populated, urban areas.

A typical example is that in Alaska, telemedicine is replacing sled dogs as the solution to medical problems. As a representative of the vast and sparsely populated, in case of emergency, medical staffs must load up patient records on a sled with a dog team and make the 30-day journey to Some extremely remote locations. According to a report on The status of telemedicine in Alaska, current telemedicine including the following service contents: 1. Sharing of pre-stored patient information; 2. Live (Real-Time) consultation between the distant site physician or practitioner and the patient; 3. Self-monitoring or Testing by provided mobile device. In recent years, telemedicine has become a "disruptive" innovation, which challenging the health care delivery status quo and fundamentally altering the patient experience [15].

Another attempt of telemedicine in Asia is led by Kyushu University, which is called Portable health clinic (PHC) system. It is a compact telehealth system with diagnostic equipment and GramHealth software for archiving and searching patients' past health records [16]. Diagnostic items including detections for blood glucose, urine glucose, pulse rate, body temperature, height, weight, BMI, waist hip ratio and so on. Take into account the expertise required to operate, a trained healthcare lady was introduced into this system. A PHC briefcase with diagnostic equipment in it is designed to be low cost and portable. By carrying the PHC briefcase, a temporary medical site can be set up quickly in one village, and after examinations, the data will be transferred to the network cloud and be analyzed by doctors in medical center. Initially PHC aimed to deliver telemedicine supported healthcare services to the people in remote areas. However, people are gradually realizing that PHC could also be used for an aging urban society. So far the PHC system has been PHC has been rolled out in Bangladesh, India, Pakistan, Thailand, Cambodia and Liberia, thousands of people have received medical services from this project [17].

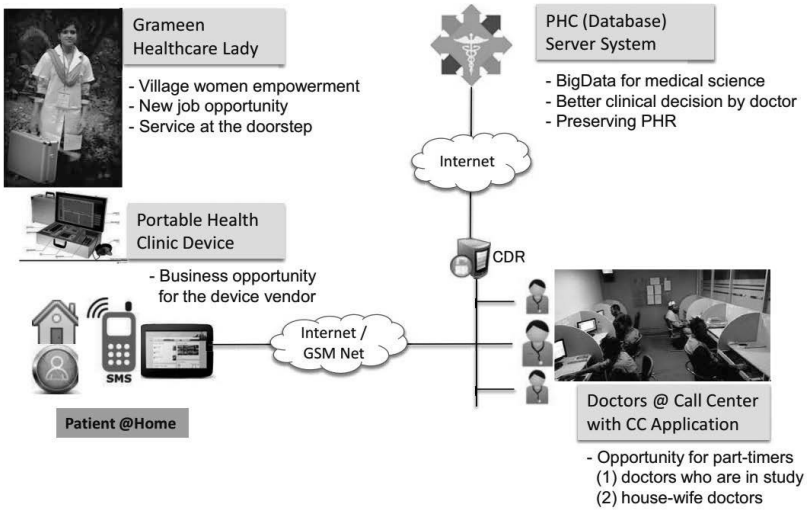

Figure 2. Operation model of PHC system [18].

3. Telemedicine in COVID-19 outbreak:

So far the role:

At the beginning 2020, Chinese authorities made the first public announcement that a new type of virus was rampant in the city of Wuhan. Common symptoms of COVID-19 include fever, cough, fatigue, breathing difficulties, and loss of smell and taste [19]. Although most people have mild symptoms, some people develop acute respiratory distress syndrome (ARDS), and eventually lead to death. More worryingly, even the patients who have recovered from the acute phase of the disease but continue to experience a range of effects for months afterwards, including severe fatigue, memory loss and other cognitive issues, low grade fever, muscle weakness, and breathlessness[20] [21].

COVID-19 mainly spreads through the air, A new infection could easily occur when virus-containing particles exhaled by an infected person, either

respiratory droplets or aerosols, get into the mouth, nose, or eyes of other people who are in close contact with the infected person. By October 2020, over 37 million COVID-19 cases and 1 million deaths have been reported globally [22]. Isolation is considered the most effective way to prevent the spread of the virus. Therefore, telemedicine could be one of the effective ways to provide necessary medical services while minimizing the hazard of direct person-to-person exposure.

Using of telemedicine mainly focus on self and distance monitoring, treatment, patients after discharge in health centers (follow-ups) and implementation of online health services. According to the recent reports, Telemedicine could help rapidly integrate information of confirmed cases, free up medical staff and equipment required for those who become seriously ill from COVID-19. Additionally, by not congregating in small spaces like waiting rooms, telemedicine could reduce the risk of nosocomial cluster transmission, which protect patients, clinicians, and the community from exposure to infection, and finally diminish the burden on the healthcare providers and health system [23].

Triage by telemedicine:

As one of the important functions in telemedicine, triage by telemedicine has been taken seriously in many countries. However, because of the shortage of medical staffs, one-on-one inquiring diagnosis is almost impossible. The most common alternative form is online self-assessment tools. People who want to know if they are infected usually compare their symptoms through an online questionnaire, the symptoms description on websites usually come from the publications from World Health Organization or relevant national institutions. Those websites relieve people's anxiety to some extent, save the offline medical resources, however, there are still some shortcomings, such as:

1. Non-uniform diagnostic criteria

Most online triage systems are sponsored by corporations, although most of the symptoms are generally admitted, some detailed diagnostic criteria such as fever temperature, the definition of social distance and close contact varies in different tests. Additionally, the length of the questionnaire on different websites are also different. Without an official uniform criteria, the accuracy of some web questionnaires is still questionable.

2. The waste of information resources

   The exchange of information is a two-way street, during people do self-assessment online, it is possible to integrate the valuable information, especially the epidemiology information, such as contact history, travel history, surrounding community situation of the suspected cases. Unfortunately, because such the online counseling is scattered, it is difficult to integrate the data and use them for big data epidemiological analysis.

3. Difficult to carry out in remote areas.

   Although the Internet has gained popularity in some countries, it is still difficult for rural people in remote areas to access the Internet, especially in developing countries. In some populated areas, even if there is a community infection, the detection rate is still inadequate, it involves many factors such as traditional ideas about disease, the lack of knowledge and inadequate medical publicity.

Based on these, a plan to build a telemedicine consulting platform for COVID-19 has been proposed by Kyushu university. By cooperating with local medical institutions and companies, professor Nakajima's group plan to provide telephone triage to people in remote areas. Diagnostic criteria in telephone questionnaire are unified from WHO and each national official standards. The triage will be carried out by the staff of the medical center, and information from interviewees will be used for future epidemiological

studies. The project could not only relieve the detection pressure of COVID-19 in remote areas, but also expected to enhance the understanding of people to COVID-19, and promote the cooperation among countries in telemedicine.

Summary:

We reviewed the history, applications of telemedicine. Telemedicine is a broad, coherent concept that play diverse roles in different medical processes. It involves medical knowledge education, triage, remote clinical treatment, post-treatment consultation and long-term health care. The outbreak of COVID-19 gives boost to telemedicine development, a professionalized and internationalized telemedicine platform will show infinite application prospect in the future.

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