

The Prospect of the Fourth Industrial Revolution and Home Healthcare in Super-Aged Society

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The advent of the fourth industrial revolution which combines the physical, digital, and biological spaces based on the information and communication technology (ICT) is changing the paradigm of the healthcare industry. As the concept of “aging-in-place” and wellness are attracting attention in super-aged society, smart care has been noticed as a core service for home healthcare. The effectiveness of remote medical services using smart devices has already been confirmed, and a hospital in the home may be recognized as another medical unit in the next 10 years. Though, prior to the expansion of home healthcare services, it is necessary to review the related considerations and response strategies to minimize potential risks. By means of appropriate utilization of biometric information from digital technologies and institutional supports, a human-centered home healthcare is expected to establish accurate, safe, and sustainable services in tandem with the fourth industrial revolution.

Key Words: Fourth industrial revolution, Home care services, Aging

INTRODUCTION

What is the fourth industrial revolution? The remarkable technological advances of the civilized society over the past two centuries since the first industrial revolution have been phenomenal in human history¹⁾. The first industrial revolution is called the “mechanical revolution” and refers to the period when the production system centered on the domestic industry was changed to the factory production system by the advent of the steam engine in the middle of the 18th century. The second industrial revolution, which is called the “energy revolution”, has enabled mass production with the emergence of electric power. In the era of the third industrial revolution, represented by the “digital revolution”, our society has evolved into computerized information and automation system by the development of computers and information and communication technology (ICT). The “fourth industrial revolution”, announced at the World Economic Forum in January 2016, has been released as a technological revolution that fuses the boundaries of physical space, digital space, and biological space based on the third industrial revolution¹⁾. This fourth industrial revolution, based on the cyber-physical system, is expected to have a significant impact

on the industrial structure and market economy model around the world. Its nature of “hyper-connectivity” and “super-intelligence” will transform everything into interconnected and more intelligent society²⁾. Above all, big data, produced in the Internet of Things (IoT) environment, in which all things including humans and objects are connected, and the realization of artificial intelligence (AI) that processes and utilizes big data, has led to a smarter intelligence information society.

Nowhere does the IoT offer greater promise than the field of healthcare, where its principles are already being applied to improve access to care, increase the quality of care, and reduce the cost of care³⁾. Many countries around the world are becoming aged societies (over 14% of the population aged over 65 years), and Japan, German, and Italy already became super-aged societies (over 20% of the population aged over 65 years). Korea will become a super-aged society within the next 10 years. A rapidly aging society and the increase in the income level have drawn consumers’ attention to the interest in the quality of life and healthy aging. As the nation becomes older, the demand for an effective care service keeps getting higher⁴⁾. Hence, the technology-supported homecare environments are cited as a promising solution to take care of the growing number of elderly and disabled people⁵⁾. In this review, how the super-

aged society can be influenced, especially in terms of future geriatric care based on home healthcare under the fourth industrial revolution is discussed.

THE FOURTH INDUSTRIAL REVOLUTION AND HOME HEALTHCARE

Many of the “tipping points: moments when specific technological shifts hit mainstream society” of the fourth industrial revolution presented in the World Economic Forum are related to the healthcare industry (Table 1)⁶. Gartner, an American research and advisory firm, estimated the economic value created by the IoT market to be about US \$1.9 trillion by 2020, with a weighting of 15% (about US \$285 billion) in the healthcare sector⁷. ICT-based services that have crossed the boundaries of time and space have collaborated with the medical and healthcare industry leading to telemedicine, robotic surgery, AI-based care, and proactive diagnosis using big data. Such changes are transmuting the quality of healthcare services. What it makes for “smart care” using ICT-based services, is the role of assisting the provision of healthcare to individuals outside the hospital as well as in-patients. Particularly in the mid-2020s, the development of intelligent sensors is expected to actualize “connected home,” in which everything is connected to the Internet to provide

data-based services⁸. In other words, it is a human-centered reforming healthcare home, where intelligent information devices interact with people through a network; for example, an in-home monitoring system for patients with dementia in the UK⁹. Kim et al.¹⁰ pointed out the limitations of hospital-centered medical care in a super-aged society and commented that digital technology would contribute to realizing “aging-in-place,” wherein one can spend their old age in the home and community, where they have lived their entire lifetime, until the end of their life.

FROM THE HOSPITAL TO COMMUNITY OR HOME

In the past, a doctor was a grateful person who came home when we were sick, but in modern times, it is hard to imagine. Instead, hospitals and institution-based medical services have been dominant. In the healthcare domain across the world, aging is the biggest issue. Korea is the fastest aging society in the world. By 2050, the ratio of 65-year-old and over in Korea is expected to reach 40%, the oldest population in the world, alongside Japan and Italy¹¹. With respect to one’s desire to pursue happiness, it is not acceptable that one should spend their old age in hospitals or long-term care facilities because of being sick and die at

Table 1. Tipping points expected to occur by 2025

Tipping points	(%)
10% of the people wearing clothes connected to the Internet	91.2
90% of the people having unlimited and free (advertising-supported) storage	91.0
1 trillion sensors connected to the Internet	89.2
The first robotic pharmacist in the US	86.5
10% of the reading glasses connected to the Internet	85.5
80% of the people with a digital presence on the Internet	84.4
The first 3D-printed car in production	84.1
The first government to replace its census with big-data sources	82.9
The first implantable mobile phone available commercially	81.7
5% of the consumer products printed in 3D	81.1
90% of the population using smartphones	80.7
90% of the population with regular access to the Internet	78.8
Driverless cars equaling 10% of all the cars on the roads in the US	78.2
The first transplant of a 3D-printed liver	76.4
30% of the corporate audits performed by AI	75.4
Tax collected for the first time by a government via a blockchain	73.1
Over 50% of the Internet traffic to homes for appliances and devices	69.9
More global trips/journeys via car sharing than in private cars	67.2
The first city with more than 50,000 people and no traffic lights	63.7
10% of the global gross domestic product stored on blockchain technology	57.9
The first AI machine on a corporate board of directors	45.2

3D, 3-dimensional; AI, artificial intelligence.

Adapted from World Economic Forum (2015)⁶.



Fig. 1. Smart care for home healthcare services.

a hospital. Therefore, a medical system and culture that can provide treatment and medical care in the place where one has spent their later life and end of life are becoming the direction of future medical care. With the introduction of telemedicine and IoT technology in healthcare, it is increasingly expected that “home” can be regarded as the hospital itself (Fig. 1).

Smart care applications are actively under development and expected to become popular soon. For example, digital coaching for chronic diseases using wearable sensors¹²⁾ and smart vest for measuring the heart rate, body temperature, blood pressure, electrocardiogram, and galvanic skin response are being tested to monitor the patients’ physiological signs¹³⁾. In addition, smart devices that help people with disabilities and the elderly in their daily lives, including home-based care robots¹⁴⁾, are being rapidly noticed. As a result, individual health management becomes easier, and an individual will be able to become involved in his or her health problems more actively. In the recent studies, it was confirmed that the efficacy and effectiveness of the management of hypertension, diabetes, and metabolic syndrome could be improved through smart care services including telemedicine¹⁵⁻¹⁷⁾. Currently, the medical care delivery system in Korea consists of primary medical care, secondary mid-sized hospitals, and tertiary care hospitals, but home healthcare may be recognized as another medical unit in the next 10 years. In other words, the concept of hospital in the home (HITH) will emerge as a new paradigm of medical care. The New South Wales Health Authority has already established the HITH guideline to develop a form of patient-centered healthcare system that is closely linked to hospitals and com-

munities¹⁸⁾. In addition, with the point that proactive health and disease management based on life patterns are possible, the scope of home healthcare will be expanded to general population interested in wellness.

ANTICIPATED ISSUES AND RESPONSE STRATEGIES

In the next decade, when the fourth industrial revolution era is in full swing, a variety of smart healthcare devices will be developed based on the technological progress in ICT and AI convergence. New therapeutic and healthcare services utilizing these technologies will emerge¹⁹⁾. It is naturally expected that it will enhance the health conditions and quality of life of individuals, expand welfare and also promote economic growth as a new growth engine. However, it is essential that new medical technology and services are evaluated for their effectiveness in healthcare systems in order to minimize potential risks. The specific considerations and corresponding strategies are summarized as follows.

1. Technology Level of Home Healthcare Devices, Data Processing, and Analysis

Smart healthcare devices launched at the current stage of research or in some markets have once succeeded in recognizing new medical paradigms for patients and healthcare providers. However, it remains to be seen whether these devices or services can replace the current general treatments and health practices from pilot trials. Despite ensuring considerable enhancement by innovative technologies in the

fourth industrial revolution, it is still uncertain that it will be put into practice in the healthcare system within the next decade. Even if mechanical accuracy is innovatively improved, there are many concerns.

The first concern is the complexity of health-related information of the patients. Not only are the types of health-related information varied, but there are also differences based on gender, age, ethnicity, etc. Furthermore, intelligent home healthcare services rely on appropriate and sufficient information from users²⁰. Therefore, information should be sorted and adopted according to priorities to reflect the real-time situations and problems well. However, because information tends to be greatly volatile over time, a large amount of data that surpasses one's imagination is produced even when monitoring just one disease-related information.

Second, usually, patient information is exceptional and beyond regularity. We are often confronted with uncertain situations in patient care or being at risk beyond prediction, although it does not end with a medical accident. Even with 99% accurate information, 1% of false information can lead to inaccurate prescription and inadequate management and can be extremely dangerous to the patient's life. For example, IBM's AI "Watson" uses big data in the area of oncology to recommend the best treatment for each patient. Although there is an advantage in reducing human errors, in the case of various treatment options or biomarkers, Watson's opinions were inconsistent with those of human doctors²¹. The countermeasures against unusual situations are also challenged as a big limitation in the development of technology for the practical use of autonomous vehicles. Strict verification of medical information from smart devices and safeguards to deal with errors in analyzing and interpreting information should be provided.

2. Clinical Evidence and Institutional Aspects

In response to the fourth industrial revolution, technology and industrial fields are anticipating the rapid and active application of new growth engines in patient care and healthcare markets. However, healthcare policy and systems that promote and support the expansion of the demand for digital healthcare or mobile health are yet to be discussed on the table. Although passive and conservative responses of medical practitioners have been criticized for this reason, it is a popular opinion that premature adoption is not desirable for the proper development of a healthcare system in the current situation, where the clinical experiences and evidence for smart health or telemedicine are rarely reported.

In terms of securing clinical evidence, sufficient clinical bases should be accumulated prior to the introduction of new medical technology or system into clinical practices. Given the fast-paced technological innovation, most research

has evaluated patterns of usage and adoption of smart devices and have not much reported their effectiveness and optimized settings²². In addition, clinical practice guidelines for the application of digital health or mobile health are needed to be established through consensus of experts in each target problem or disease. A Cochrane review of the recent literature suggested that patients with chronic lung disease who used smart devices for self-management at home maintained their level of activity and improved quality of life; however, the long-term effects were unclear, and the benefits of smart homecare were not equally given to everyone. For example, it derived greater benefit with the patients who showed high interest in using smart devices²³. Bhattarai and Phillips²⁴ also suggested that digital and mobile technology could be applied to the pain management of the elderly, but the level of technology should be more advanced than the current ones, and a thorough analysis and verification of such technology demand are required. In summary, the role of smart and digital health is expected to increase in that it enables the elderly or disabled people to be monitored and receive continuous management at home. Besides, the level of clinical evidence is still weak, but there is a specific target population who show a clear effect with no serious harm or side effect.

The institutional support system is the weakest area at present. In some cases, pre-emptive systems and legislation support systems can be a breakthrough opportunity to expand the relevant fields. According to Article 34 of the Medical Act in Korea, remote medical services between doctors and patients is not allowed; thus, it is impossible to provide formal medical services using biometric information collected through wearable devices. In the United States, telemedicine is commonplace, and since 2015, Japan has also allowed telemedicine services for specific patients²⁵. Korea has also been trying to introduce telemedicine between doctors and patients under the label "U-health" through pilot projects but has failed in professional and social consensus due to the controversy of medical privatization^{25,26}.

Therefore, it is urgently required to establish a clinical basis for home healthcare that will become a key field in the fourth industrial revolution for the next decade. There should be a digital and mobile health application model that reflects the development of new ICT convergence technology, and it can be considered as a process of creating evidence and establishing consensus through clinical trials, performance studies, and pilot projects. In the meantime, standard guidelines for health and medical information should be prepared including the revision of the Medical Act.

3. Aspects of Protection for Personal Information

In the collection of biometric information based on IoT, a careful review of the vulnerability of personal information

protection and possible violations of human rights is required. As IoT presupposes the collection and use of vast amounts of data, it inevitably increases the likelihood of infringement of personal information. Moreover, the utilization of big data raises the possibility of misusing it other than for its original purpose. In addition, due to the increase of collaboration between various services, personal information sharing can be frequent, and the subject of information destruction is also vague. Korea is a country with the highest level of privacy-related regulations and has stronger regulatory means for protecting personal information than other advanced countries²⁷⁾. It cannot be said that a high level of regulation protects personal information efficiently and effectively. Rather, unnecessary reinforcement of regulations may hinder new industry growth²⁵⁾. Therefore, personal information protection should be improved in the direction of increasing the degree of freedom of service development using data while strengthening the protection of users' information. As one of the alternatives, "de-identification method of personal information" was proposed. In addition, since data collection takes place in situations wherein the subject is not fully recognized in the IoT environment, the user or patient should take control of the data after its collection (e.g., withdrawal of consent, right to access personal information, notification of using personal information)²⁸⁾. The most effective and acceptable principles for the development of personal information protection legislation are required through the soft law approach which respects self-regulation²⁹⁾.

CONCLUSION AND SUGGESTIONS

The technical, clinical, and institutional strategies for home healthcare are summarized as follows: (1) Rigorous verification and safeguards should be provided along with technological progress considering the complexity and exceptionality of biometric information. (2) It is necessary to develop a home healthcare model that fits the needs of the elderly society and establish a legal, institutional support system including the consensus of experts by certifying clinical evidence and standard clinical guidelines for using medical information and healthcare service applications. In particular, experts in the universities or hospitals should take the leading role in securing the basis of evidence from clinical trials and reaching consensus through consultation with healthcare professionals in primary care and health authorities. (3) The acceptable principles should be developed to use health information while ensuring personal information is protected clearly.

A concrete action plan based on these strategies will be needed. Unfortunately, home healthcare for the elderly and disabled healthcare system has not been successful in Korea yet. Only a few elements in various fields, such as visiting healthcare³⁰⁾, visiting nursing care³¹⁾, visiting rehabilitation

treatment^{32,33)}, and visiting welfare service^{34,35)} remain in the discussion and research levels. In order to achieve home healthcare that meets the reality of Korea during the fourth industrial revolution era, first, home healthcare experience performed by healthcare professionals should be accumulated. It may be an urgent task for healthcare professionals to prepare for the next decade.

Several social issues due to the fourth industrial revolution will change the paradigm of the medical system and have a strong impact on the health industry as a whole. There are many controversies because of the concern that the technological revolution will replace people's roles and abilities. However, since a consumer and a provider of services are both "humans" in the healthcare industry, the core value of "all services are relationships between people" is emphasized the most than in any other industries. The technologies will fail unless humans are at the center of them. Such remarkable innovations of the medical field in the fourth industrial revolution will enable (1) accurate decision-making by medical personnel, and (2) providing diversified, safe, rapid, and sustainable healthcare services. By this, future medical care will function better with intelligent human-centered services that are dedicated and service-oriented.

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