

Review Article



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Conflict of Interest

The authors declare that they have no competing interests.

A New Paradigm for Clinical Nutrition Services in the Era of the Fourth Industrial Revolution

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ABSTRACT

The role of clinical nutrition services is emphasized in the care of chronic diseases; the prevalence of chronic diseases continues to increase due to the living environment change, westernized dietary life and the aging population in Korea. The effectiveness of clinical nutrition services in the treatment of diseases in inpatients has been demonstrated in several studies. However, in recent days, innovative changes are pursued in clinical nutrition services through a convergence with information and communication technology (ICT), a core technology of the fourth industrial revolution such as big data, deep learning, and artificial intelligence (AI). The health care environment is changing from a medical treatment-oriented service to a preventive and personalized paradigm. Furthermore, we live in an era of personalization where we can personalize dietary aspects including food choice, cooking recipes, and nutrition in daily life. In addition, ICT technology can build a personalized nutrition platform in consideration of individual patient's diseases, genetic trait, and environment, all of which can be technical means in personalized nutrition management services. Personalized nutrition based on ICT technology is able to provide more standardized and high-quality clinical nutrition services to the patients. The purpose of this review is to examine the core technologies of the fourth industrial revolution affecting clinical nutrition services, and ultimately discuss how clinical nutrition professional should respond to ICT technology-related fields in the era of the new technological innovations.

Keywords: Clinical nutrition service; Personalized nutrition; Fourth industrial revolution; Information and communication technology

INTRODUCTION

The life expectancy of the Korean continues to increase from 82.7 years in 2018, but the healthy life expectancy has decreased from 65.7 years in 2012 to 64.4 years in 2018 [1]. This recent trends in life expectancy in Korea is related to the increased prevalence of chronic diseases due to the rapid change in living environment and the aging population, and increased disease duration affects the lives of modern people in many aspects [2]. These circumstances lead the public increase their out-of-pocket medical expenses every year [3].

It has been reported that about 50% of patients admitted to medical institutions are malnourished, and even after discharge, the rate of readmission for those patients has increased due to malnutrition or an exposure to nutritional risk [4]. To solve this problem, the clinical dietitians provide clinical nutrition services to patients, which can improve patients' nutritional status and shorten hospital stay, reduce medical expenses [5-7]. With the emphasis on the need for systematic management of nutritional problems by government policy, the 'National Nutrition Management Act' was enacted in 2010 to implement the nationally qualified clinical dietitian system in Korea [8]. As a result, the statements about development of the clinical nutrition field and the foundation for the qualitative management of clinical nutrition services, were laid down in the statute. In addition, job standards for clinical dietitians has been developed and lead to improved qualitative services in practice of clinical nutrition service [9].

In the rapidly changing health care environment with the advent of the fourth industrial revolution, clinical nutrition professionals need to strengthen their capabilities and to consider new innovative roles to meet the international level of clinical nutrition services. It is necessary to find a way to improve the quality of medical care by providing disease-preventing health management and personalized health services, through the core technologies leading the fourth industrial revolution including artificial intelligence (AI), information technology (IT), big data, genomics, etc. [10]. The next generation of clinical nutrition professionals should actively respond to paradigm shifts in the health care environment and create new roles in the field of clinical nutrition services through cooperation and convergence with new technologies [11].

Therefore, the purpose of this paper is to understand the development process and status of clinical nutrition services in Korea, and to analyze the impact and relevance of core technologies in the era of the fourth industrial revolution on clinical nutrition services. In addition, this review tried to build the roles of clinical nutrition professionals who can anticipate the future of clinical nutrition services and react to the changing situation in the new era of technological revolution.

INSTITUTIONAL DEVELOPMENT PROCESS OF CLINICAL NUTRITION SERVICE

The starting point of contributing to the institutional development of clinical nutrition services in Korea is that the Korean Dietetic Association, a private institution, has operated a private clinical dietitian qualification system since 1997 [12]. These efforts to specialize in clinical nutrition services mainly centered on private institutions and researchers have come to a new phase in which legal grounds for national policy support are established, with the enactment of the 'National Nutrition Management Act' on March 26, 2010 and the 'Enforcement Decree of National Nutrition Management Act' on September 27, 2010 [8,13]. According to the National Nutrition Management Act, it contains information on national nutrition management plan establishment and implementation, the implementation of nutrition management business, national nutrition and dietary survey, license and education of dietitian, and etc. It also accommodates the establishment of a clinical dietitian qualification that contributes to improving the nutrition and health management of the people and the quality of life through clinical nutrition services [8]. Article 22 of the enforcement regulations of the National Nutrition Management Act describes the work of a clinical dietitian

as follows: “A clinical dietitian performs the following tasks for disease prevention and management; Specialized tasks for each disease: nutrition assessment, nutrition counseling and education, nutrition monitoring and evaluation, nutrition management to improve malnutrition, clinical nutrition consulting and research, and other tasks related to clinical nutrition.” As above, the roles of the clinical nutrition professional to perform specialized tasks was clearly presented [13]. In addition, the Ministry of Health and Welfare's research report defined that “Certified clinical dietitian is a professional who performs clinical nutrition therapy for disease treatment and prevention for individuals and groups with nutritional problems or potential risk factors.” As shown, clinical dietitian is described as the main manpower who performs clinical nutrition services in the clinical fields [9].

In addition, the Korean Institute of Dietetic Education and Evaluation (KIDEE) was established on March 11, 2011 with permission from the Ministry of Health and Welfare, and was commissioned to administer the first clinical dietitian national qualification test in 2012 [14]. KIDEE was established mainly to carry out tasks such as dietitian education-related research, education certification evaluation project for dietitian, clinical dietitian education and qualification management in order to guarantee the quality of nutrition services and to cultivate competent dietitians and professional dietitians for social needs. It contributes to the development of the clinical dietitian system [14].

Since then, systematic policies to establish the infrastructure and institutional framework for clinical nutrition services have been continuously promoted. Since 2010, the operation of the nutrition support team (NST) has been included among the evaluation items of the medical institution health care accreditation and NST members operate as a team centered on doctors, nurses, pharmacists, and clinical dietitians [15]. After that, in August 2014, the details of the standards and methods for applying medical care benefits under the National Health Insurance Act were revised, and the ‘therapy by nutrition support team’ became a medical cost. Therefore, interest in NST activities has increased, and efforts are being made to standardize work for each disease [15]. The Ministry of Health and Welfare promoted clinical dietitian manpower supply and work environment improvement by requiring clinical dietitians to be defined as health care professionals in Act on Providing Assistance with Health Professionals in 2019 [16]. Also, the Ministry of Health and Welfare promoted a chronic disease management pilot project in primary medical institutions in 2019 in order to extend the healthy life expectancy and improve the quality of life for patients with chronic disease. Various policies related to clinical nutrition services are in place, such as hiring a dietitian as a health care coordinator in primary medical institutions and reflecting the cost of education and counseling [17].

CURRENT STATUS OF CLINICAL NUTRITION SERVICES

Based on a number of previous studies, positive effects such as improvement in the health outcome of the patient's disease have been confirmed by the active intervention of clinical nutrition services in the treatment of inpatients [18,19]. The results of a meta-analysis on the effectiveness of clinical nutrition services have shown that clinical nutrition services performed by clinical dietitians are significantly effective in treating diseases after nutritional intervention. This was an opportunity to confirm the importance of a clinical dietitian in charge of clinical nutrition services [20]. Actually, medical staffs generally recognized that clinical nutrition service was important in a patient treatment, the demand for clinical

nutrition services was high, and the demand of clinical nutrition professional for each disease was also high [21]. It is emphasized that the positive recognition of the medical staff on the qualitative effect of clinical nutrition services in patient treatment is more desirable than that of the medical staff on the provision of clinical nutrition services [22].

Evidence-based medicine has expanded worldwide since the 1990s for qualitative medical treatment, and standardization of work has been required in other health-related fields such as nursing [23]. In order to reduce the qualitative difference in clinical nutrition services performed in each medical institution, it was urgent to achieve job standardization by analyzing job characteristics and trends of clinical dietitians [24]. Accordingly, with the support of the Ministry of Health and Welfare, the job standard of clinical dietitian was developed. Also, for representative chronic diseases with high demand for clinical nutrition services such as diabetes, cancer, and dyslipidemia, customized clinical nutrition job standard and implementation guideline for each disease that can be effectively applied in the clinical field were developed [25]. In other words, by describing the work contents related to clinical nutrition treatment for each disease through introducing the concept of nutrition care process (NCP), it was helpful to establish the direction of professional nutrition management work in the clinical field [9].

As a result of surveying the clinical nutrition services for general hospitals in Korea, the majority of malnourished patients hospitalized were not able to receive clinical nutrition services, and the main cause of this situation was the shortage of clinical dietitians [26]. Therefore, it is expected that clinical nutrition services will be activated in the future by providing basic data necessary for policy preparation, such as the establishment of appropriate staffing standards for clinical dietitians and calculation of education fees through standardization of clinical dietitian duties [9,23]. As such, by presenting a model for clinical nutrition service work, the work of clinical dietitian has been standardized, and efforts has been made to ensure that clinical nutrition service in Korea meets the international level, contributing to the improvement of nutrition and health of the public [25].

FUTURE PROSPECTS OF CLINICAL NUTRITION SERVICES ACCORDING TO THE ERA OF THE FOURTH INDUSTRIAL REVOLUTION

In 2016, the world economic forum (WEF) predicted that the social and economic structure of the world is radically changed by new technological innovations with the advent of the fourth industrial revolution [27]. Following the third industrial revolution which has developed into an information and automation-oriented society based on computers and the internet, the fourth industrial revolution opens an era of superintelligence and hyperconnectivity in which everything is connected with the intellectualization of physical systems. This means that new values are created by fusion with information and communication technology (ICT) such as big data, AI, and mobile [28].

To solve social problems such as an increase in chronic diseases in Korea and an increase in medical expenses due to an aging population, medical and health care industry, which is fused with ICT technology, is promoting a change from a medical treatment-oriented service to a 4P-centered paradigm, which is preventive, predictive, personalized, and participatory

[29]. In addition, according to the 2nd master plans for national nutrition management announced by the Ministry of Health and Welfare in 2017, it is reported that it aims for active nutrition management that enhances the accessibility of the nutrition management service for the people and improves the individual's nutrition care ability and practice [30]. Hence, clinical nutrition service is essential to react to recent paradigm shift in medical and public health care and for active nutrition management. Since the dietary life of the fourth industrial revolution is changing in terms of food choice, cooking method, and nutrition care, the use of ICT technology can contribute to the development of future clinical nutrition services [31]. **Figure 1** represents a frame that shows the challenges that clinical nutrition professionals need to move forward as a way to access integrated and standardized precision nutrition in response to the new era of technological revolution [32]. In the following, we will look at the changes in the food and health care industry according to the fourth industrial revolution and the future prospects of clinical nutrition services based on ICT technology.

Personalized nutrition based on genomics

With the recent development of genomics, personalized medicine and precision medicine, which diagnose and treat according to an individual's genotype, have become a reality, and interest in personalized nutrition is also increasing [33]. The ultimate goal of personalized nutrition is a tailored nutrition approach that is personalized to nutritional requirements, taking into account individual genetics, metabolism, and environmental interactions to prevent and treat diseases and promote health [34]. It has a similar meaning to precision nutrition, individualized nutrition, and nutritional genomics [35]. ICT technology is one of the technical means for a tailored nutritional access, and it is possible to build a personalized nutrition platform by collecting and integrating personal information (genetic trait, metabolism, environment) [36]. Furthermore, if a clinical dietitian adopts this technique and uses it as a tool to evaluate NCP, it will be possible to provide accurate and reliable personalized nutrition through a more standardized NCP as shown in **Figure 2** [37].

Application of food tech and smart health care to clinical nutrition service

As the fourth industrial revolution emerged as an innovative trend of the times, the existing food and medical industries have accelerated the convergence of ICT technologies such as AI

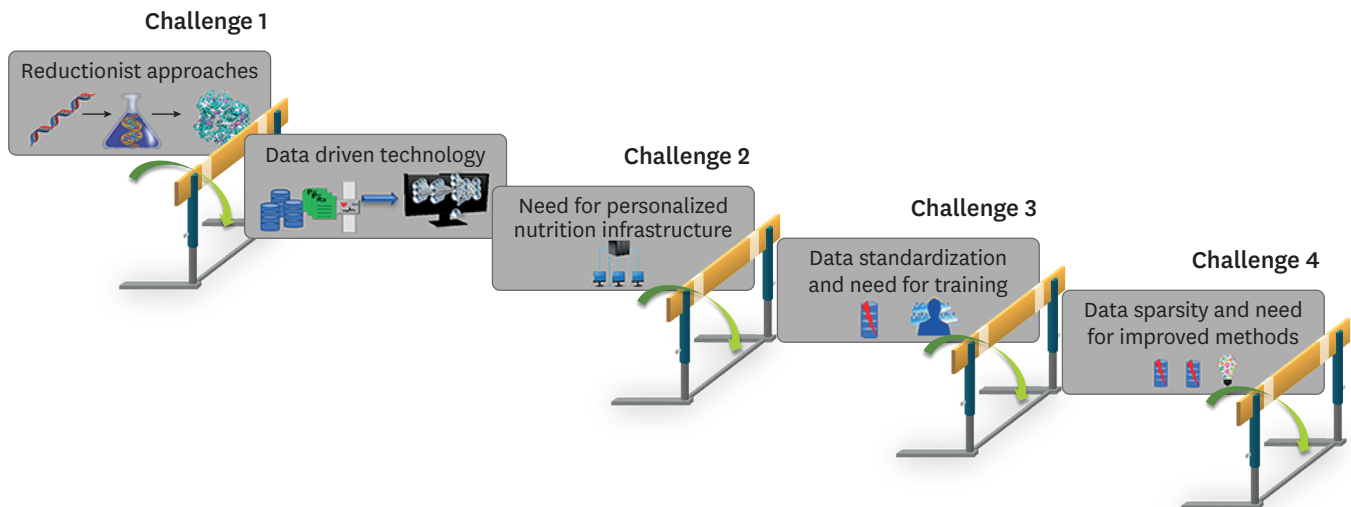


Figure 1. Challenges in personalized nutrition. **Figure 1** was adapted from Verma et al. (2018) [32].

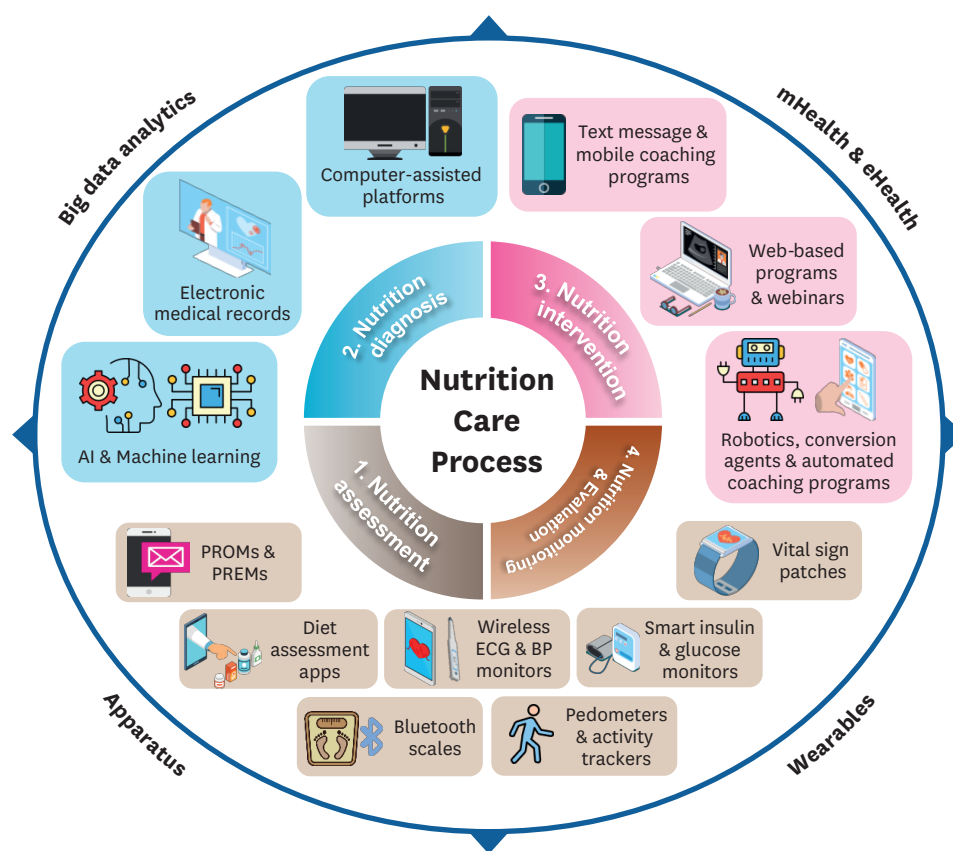


Figure 2. Digital health technologies to implement the four steps in the nutrition care process. **Figure 2** was modified from Kelly et al. (2020) [37].

There are barriers including policy & regulation, data safety, interoperability, evidence-base to address for wider adoption in primary and secondary care.

BP, blood pressure; ECG, electrocardiogram; PREM, patient-reported experience measures; PROM, patient-reported outcome measures. mHealth:mobile Health care; eHealth; internet based Health care.

and big data. Accordingly, food tech industry and smart health care industry have received attention [29,38]. Food tech is a compound word of food and technology that applies ICT technology throughout the development, production, distribution, cooking and processing of food. In particular, the introduction of 3-dimensional (3D) food printing, smart kitchen robots, and platforms in the field of cooking and processing is changing the overall dietary life [38]. ‘Smooth food’ of Biozoon, a German food company, is a softening food for the elderly, developed for elderly patients with eating disorders with the support of the European Union (EU). In ‘smooth food’, foods such as potatoes, chicken, broccoli, and cabbage were used for 3D food printing, and the shape was reconstructed by considering the texture and appearance, not crushed foods [39]. A 3D food printing currently does not have a high market share in Korea, but it is possible to improve qualities of life by producing personalized foods considering not only the texture, but also taste, aroma, palatability and nutrients based on individual's physical and nutritional status [40]. The Moley Robotics Kitchen of Moley Robotics, the first robot chef in the world, uses big data, deep learning, and AI technology to prepare food, cooking, and even clean kitchen, and thus automated and intelligent systems enable free movement in the kitchen, and balanced dietary life is possible through customized cooking [41].

ICT technology is also being used in the health care industry. National IT Industry Promotion Agency defines smart health care as “a personalized medical service that monitors and manages patients' health and disease status in real time without space and time constraints by combining ICT technology and medical technology.” [29]. With the development of technology suitable for health care, health and medical service industries have become the center of the smart health care industry, and medical service provision is expanding not only in medical institutions, but also in daily life such as sports, daily activity records, and personal diet [42]. In addition, consumers of health care services have changed from passive patients to active and proactive medical consumers, including healthy people [43]. These services are expected to create high value added effect, such as increasing healthy life expectancy and alleviating the national medical financial burden by managing the entire life cycle from pre-diagnosis, pre-treatment, follow-up management, and health maintenance [44]. As ICT technology is applied to health care services, smart health care services are actively implemented, which enable personalized health management through big data platform construction, big data-based AI, and mobile devices for health monitoring and management [45].

Big data and clinical nutrition service

As the number of health care devices capable of implementing mobility and connectivity increases, a large amount of data is continuously generated, and the big data market able to integrate and utilize data is growing rapidly [42]. Big data analysis aims to support decision making or draw conclusions based on grounds with accuracy and objectivity by deriving correlations between data [46]. By establishing a platform related to health care, such as establishment of a hospital information system and nutrition management through genomic data, it is expected to have a great effect on personalized medical services [47].

Electronic medical record (EMR) collectively refers to a computerized system that manages health care data (exercise, diet, calories) and clinical data (patient information, examination records, monitoring records) of patients who visit the hospital [46]. The collected data is integrated into the cloud system in the hospital and shared with the medical staff in the hospital, enabling precise personalized diagnosis and treatment in consideration of patient characteristics and health conditions [48]. The prevalence of malnutrition in patients admitted to general hospitals was reported to be 20%–50% [49], and the Joint Commission for Accreditation of Healthcare Organization (JCAHO) of the United States recommends a nutritional screening program within 24 hours after admission. Therefore, it is assumed that a rapid NCP in the early stages of hospitalization is essential [50]. To this end, clinical dietitians analyze the patient's dietary history, physical measurements, biochemical indicators, and family history information through the collected and recorded EMR, and perform appropriate and efficient nutrition management for patients [51].

It is possible to predict diseases with high probability of occurrence or to develop personalized drugs based on genome information as the relationship between the genome of an individual and the disease is analyzed by big data technology, which has not been utilized before [52]. As an example of personalized nutrition management based on big data, ‘Sciona,’ which developed a nutrigenomic diet that combines genomic information with meals, provides nutrition and food intake guidelines that fit the genetic composition using big data related to disease. Accordingly, a personalized nutritional genome program has been developed and implemented that can reduce the incidence of diseases caused by heredity and increase the likelihood of disease prevention [53].

If the medical big data information collected through various channels is effectively used in health care services, it is possible to provide personalized medical services, improve the quality of clinical nutrition services, and increase patient satisfaction and the value of medical information [54].

Deep learning-based AI and clinical nutrition service

AI, which is emerging as a core technology leading the era of the fourth industrial revolution, is human intelligence demonstrated by machines, and is a technology that computers can perform cognition, learning, inference, and actions like humans are able to perform [55]. To implement this, it is necessary for a machine to learn an enormous amount of big data accumulated based on a deep learning technique and form an algorithm [56]. With the advent of deep learning techniques, AI constantly develops self-learned knowledge and starts to dramatically improve performance compared to the existing ones, and researches in various fields are simultaneously and rapidly progressing [57]. Especially, the size of the global AI medical market is expected to increase more than 11 times from about \$600 million in 2014 to about \$6.6 billion in 2021, and even the effect of reducing medical cost is expected [58]. Several IT companies have long entered the smart health care industry by building hospital service platforms [44]. Among them, 'Waston for Oncolgy,' an AI program of IBM's United States company called AI doctor, analyzes medical big data such as the latest clinical information, patient records, and academic journals, and recommends optimal cancer treatments to medical staff [59]. A similar domestic case is 'Dr. Answer,' a Korean AI-based precision medical project promoted with the support of the Ministry of Science and ICT. Similar to 'Waston for Oncolgy,' Dr. Answer is a program that supports diagnosis and treatment of a target disease including cardio-cerebrovascular disease, breast cancer, colon cancer, prostate cancer, dementia, epilepsy, rare genetic diseases in children, etc., with high accuracy by utilizing big data of patient life and medical care. Currently, 26 domestic medical institutions are participating in the development of project [60].

In the case of current diet applications, there is an inefficiency that users have to directly record the food intake. On the other hand, the deep learning-based 'AI diet camera' can improve eating habits by recognizing food photos taken by users, identifying food nutritional information, food intake, and eating behaviors, and performing personalized nutrition management [61]. An AI-based diet consulting platform has already appeared, and by applying the AI algorithm developed by the company, it provides personal diet management services for patients according to the type of disease [31]. In order to manage the diet for personalized nutrition, AI technology and medical services can be combined to automate the manual management of the patient's diet, which is expected to improve work efficiency and the quality of clinical nutrition services [62].

Telemedicine, mobile, wearable devices and clinical nutrition services

The need for non-face-to-face medical services, telemedicine, has increased to solve the problem of accessibility to medical care for the vulnerable as the personal movement was restricted due to the effect of coronavirus disease 2019 (COVID-19) [63]. As a result, the telemedicine market that enables nutrition management without time and space constraints using mobile and wearable devices is being activated [63].

Biometric information measured by wearable devices provided to patients with chronic disease and patients in medically vulnerable area is stored in a personal health record (PHR), and is continuously shared with medical staff, enabling telemedicine [64]. Germany's 'Vitaphone' is an electrocardiogram (ECG) monitoring telemedicine device. It measures and records the ECG,

blood pressure, body weight, and blood sugar of patients with heart disease, and information is transmitted from a remote monitoring center to medical staff in real time, so that the patients can receive immediate diagnosis and prescription in case of an emergency [65].

Currently, in Korea, telemedicine is allowed between medical staff, but telemedicine service between doctors and patients is not allowed due to safety, usefulness, and social resentment to the expansion of profitable business of medical institutions [66]. Due to these regulations, PHR services are intensively performed in domestic hospitals, and personalized medical services are provided through an algorithm that informs the proper diet according to health status and diseases based on PHR [64]. Telemedicine is not available in Korea, but pilot projects of telemedicine are being carried out step by step under the support of government agencies from the early 2000s until recently [67]. In addition, from February 24, 2020, the Ministry of Health and Welfare has temporarily allowed telephone counseling, prescriptions, and proxy prescriptions even if general patients do not visit a medical institution to strengthen COVID-19 quarantine measures [68]. Telemedicine based on untact medical services is expected to gradually become active due to improved convenience of medical service and economical aspects of the public, but social discussion and consensus of stakeholders on telemedicine is required to implement the value of telemedicine [69].

CONCLUSION

The convergence of digital technology and almost every human activity, including dietary life, is leading the fourth industrial revolution, greatly changing the daily lives of individuals and industries around the world. However, humans are the subject of the fourth industrial revolution, so human resources with subjective and convergent capabilities are needed to respond to these changes. Therefore, clinical nutrition professional must have a sense of mission to create new tasks and roles based on academic evidence by actively cooperating and converging with related fields such as IT, big data, genomics that are necessary to improve the quality of clinical nutrition services. In addition, in order to reflect social demands for health, efforts to seek efficient alternatives that can be linked to the nutrition management service industry specified in the National Nutrition Management Act and to derive industrial development are needed. As in advanced countries including the United States, it is necessary to develop a hospital-centered industry-academia-research cooperation cluster, and to establish a health management model centering on beneficiaries by integrating medical and clinical nutrition services.

It is difficult to accurately predict how much and how fast the surrounding environment related to clinical nutrition services will be changed in the near future. However, clinical nutrition professionals should recognize this social change as a new opportunity for the development of clinical nutrition, and actively devise new plans for practical use by activating linkage, cooperation, and fusion research with related fields.

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