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.

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Opportunities and challenges for contactless healthcare services in the post-COVID-19 Era

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ABSTRACT

This study examines the opportunities and challenges involved with contactless healthcare services in the post-COVID-19 pandemic era. First, we reviewed the literature to analyze contactless or contact-free healthcare services that have been utilized in pre-and during the COVID-19 pandemic periods. Then, we interviewed medical experts and hospital administrators to gain knowledge about how healthcare providers are currently working to mitigate the spread of COVID and preparing for the post-pandemic period. Thus, we analyzed the evolution and utilization of contactless services during the three different time periods: pre-, during-, and post-COVID-19. The results indicated that in the post-COVID-19 era, a new normal of hybrid healthcare services would emerge. While some of the contactless services that have been practiced during the pandemic may revert to the traditional face-to-face services, those innovative contactless healthcare services that have been proven effective during the pandemic would be practiced or even advanced in the post-pandemic period due to the accelerating technological developments. This study suggests many potential opportunities and daunting challenges for healthcare institutions, policymakers, and consumers regarding the implementation of contactless services in the post-COVID-19 era.

1. Introduction

The global outbreak of the coronavirus pandemic (COVID-19) has prompted the shift to remote work in many industries to prevent the spread of the infectious disease. As direct person-to-person contact is being circumvented, consumers' purchasing behaviors have rapidly transitioned to online media. Thus, the pandemic has helped accelerate the development of digital infrastructure in many industries (Kim, 2020). For example, organizations have developed cloud-based IT infrastructures to pursue new opportunities in offering contactless or contact-free services through mobile software, video conferencing, expanded telemedicine, e-education, telecommuting, and mobile transactions (Xiao and Fan, 2020). Considering the significant global resurgence and variants of COVID-19 and its impact on consumer behavior, as well as the trajectory of advances in digital technologies, it is reasonable to conjecture that the "contactless" age is already here (Zeng et al., 2020).

With the surge of contactless or contact-free services, various terms have been circulating in service and marketing field such as *untact* (i.e., no contact), *ontact* (i.e., contact through online media), *intact* (i.e., interactive contact: no face-to-face communication), and *digitact* (i.e., digital contact or digital face-to-face) (Hankyung, 2020). As social distancing has been encouraged or even mandated to mitigate the spread of COVID-19 (Guan et al., 2020; Lee and Lee, 2020, 2020b), companies are communicating with consumers through their real-time online marketing channels (Lee and Lee, 2020a).

The COVID-19 pandemic is expected to have lasting impacts on the traditional method of doing business in the post-pandemic era. Fortwengel (2020) suggested that COVID-19 would have permanent effects on business such as: travels that were considered important before the pandemic would be significantly diminished, flexible working arrangements and virtual work (e.g., remote work) may become more prevalent, and industries would seriously consider developing contingency plans for major disruptions in the demand and/or supply chain. Diebner et al. (2020) suggested that the development of digital functionalities has transformed many traditional face-to-face services into optional and value-added services that can be experienced either at home or in the office. For example, fitness companies now employ a digital service

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strategy to retain their customers and prevent them from becoming churners to online platforms or apps (Diebner et al., 2020).

A study by Zeng et al. (2020) reported that, as infectious COVID-19 persists, contactless services using advanced technologies are likely to infiltrate people's daily lives. Other studies suggest that the pandemic has brought new opportunities for the service industry, as digitalization of operational processes is being expedited (Bestsennyy et al., 2020; Diebner et al., 2020; Fortwengel, 2020; Fowkes et al., 2020; Kim, 2020). Specifically, the online retail industry is experiencing an unexpected renaissance owing to the rapid spread of contact-free consumption patterns (Lee and Lee 2020a); what was once considered an exclusive lifestyle of the millennial generation is now steadily manifesting in other generation groups.

According to Alicke et al. (2020), many organizations worldwide are experiencing production and logistics disruptions due to instability in their global supply chains caused by the pandemic. In the pandemic crisis, many businesses began to focus on building a "less risky", if "less efficient", supply chains. For example, many companies have started moving their core supply chains to their home countries through reshoring strategies that are blessed by their governments (Barbieri et al., 2020). Additionally, the manufacturing industry has been changing its operational structures for a more flexible and resilient production model to minimize production loss even amid the pandemic crisis (Alicke et al., 2020). Baig et al. (2020) argued that digitalization will be the most significant aspect of the global value chain strategy in the post-COVID-19 era, suggesting the need for automated operational systems that leverage big data, Internet of Things (IoT), blockchain, robots, drones, and 3D printing. Currently, COVID-19 is spreading across the globe, and it is not certain exactly when it will end.

The healthcare industry is no exception. In the digital age, many hospitals and care providers have actively pursued innovations for contactless services and operational processes for improved productivity and organizational agility (Lee and Lee, 2020b). Through applications of advanced information and communication technologies (ICTs), such as artificial intelligence (AI), Internet of Things (IoT), big data, 3D printing, virtual and augmented reality (VR/AR), smart sensors and robots, drones, etc., various contactless services have been implemented. Telemedicine, which has been widely practiced since 1990s, well before the COVID-19 pandemic period, is of course part of contactless healthcare service. However, contactless healthcare services in the digital age encompass far beyond the traditional scope of telemedicine (Marin, 2020). Dr. Bart Demaerschalk, director of the Synchronous Services Center for Connected Care of Mayo Clinic, states that "the COVID-19 pandemic has essentially accelerated U.S. digital health by about 10 years" (Marin, 2020). Accordingly, digital technology enabled contactless healthcare services have also made a big stride in their developments during the pandemic.

As of February 20, 2021, there are 110,384,747 confirmed cases and 2446,008 deaths globally due to COVID-19 (WHO, 2021). In this uncertain and fearful crisis, it is only logical to observe a boom of the various contactless services in most countries. However, as people are so eager to escape from the fatigue of social distancing during the pandemic that even some of popular contactless services may revert to traditional face-to-face services, while others may remain or even see more expanded practices in the post-pandemic era (Zeng et al., 2020). Telemedicine has also been suggested as a means to reduce medical costs and solve inefficiency problems in healthcare services (Perednia and Allen, 1995; Chen et al., 2013; Akiyama and Yoo, 2016). In addition, it is expected that the current growth trajectory of telemedicine will continue in the post-pandemic era as patients have generally been satisfied with remote healthcare services without face-to-face encounters with their doctors in the uncertain COVID-19 environment. In this study, we examine telemedicine services that have become prevalent in the healthcare industry during the pandemic and propose a strategy for effective operations of telemedicine even in the post-COVID era.

The remainder of the paper is organized as follows. In Section 2, we review the literature on the types of contactless services and categorize their delivery in pre-, during-, and post-COVID-19 periods. Section 3 presents a set of representative cases of telemedicine services that have changed the way healthcare is delivered. In Section 4, we examine opportunities and challenges concerning contactless services in the post-COVID era by summarizing the opinions of experts we interviewed in the healthcare service industry. In Section 5, we conclude the paper with a summary of the study results, implications, limitations, and suggestions for future research.

2. Literature review

As the strategic focus in most industries worldwide has shifted from product- to service-dominant logic (i.e., the perspective of servitization) and from supplier- to consumer-oriented thinking, the service industry has become the core of economy in many countries (Bell, 1976). To minimize the risk of infectious diseases, while still effectively delivering their services, most businesses have accelerated their digital transformation efforts to avoid person-to-person interactions (Kim, 2020). This shift has created an opportunity for non-face-to-face services to grow exponentially as alternative solutions to prevent the spread of COVID-19 (Lee and Lee 2020b).

2.1. Digital transformation and contactless services

With the pandemic changing all aspects of people's daily lives, there is a belief that the pre-COVID-19 normal would never return because many governments and organizations have implemented various IT-based countermeasures (e.g., the development and application of online distribution services, remote work, online education, self-diagnosis app services, and the digital tracking of confirmed cases) along with more traditional strategies to deal with COVID-19 (i.e., avoidance of direct personal contacts, social distancing in daily life, and wearing masks). As a result, contactless services have gained a renewed significance as the preferred service type by an increasing number of customers during the pandemic (Lee and Lee, 2020, 2020b).

Contactless service refers to a method of service delivery that involves indirect interactions between people (e.g., person-machine/person-machine-person), instead of the traditional methods that involve direct person-to-person interactions (Kim et al., 2018). Lee and Lee (2020a) defined an untact (contactless) service as a "service that is provided without face-to-face encounters between employees and customers through digital technologies." They further presented the enabling technology for contactless service as a form of digital transformation because it made the service paradigm shift possible from personal customer interactions to intangible interactions based on advanced technologies. Contactless services are generally delivered by advanced technologies, such as artificial intelligence (AI), Internet of Things (IoT), virtual reality (VR) and/or augmented reality (AR), big data, and cloud-based platforms (Lee and Lee, 2020a). Thus, different types of contactless services have been developed based on consumers' needs, while providing personalized customer experiences (Kim et al., 2018; Sweeney et al., 2015; Verleye, 2015; Lee, 2018, 2019).

It is clear that contactless service innovations would not have been possible without advanced technologies (Lee and Lee 2020a). For example, to effectively prevent the spread of COVID-19 in South Korea, the government instituted a quarantine system based on a digital healthcare protocol that included contactless drive-through tests for the first time in the world, requiring cutting-edge technologies. The rapid advances in information and communication technologies (ICTs) enable innovation and diffusion of contactless services worldwide (Lee and Lee, 2020a).

There are several key reasons for the rapid spread of contactless services. First, the use of contactless services had already been prevalent in the distribution industry (Kim et al., 2018). Specifically, consumers who did not want direct contact with employees (e.g., going to a store or

accessing products or services face-to-face) were provided with non-face-to-face or indirect contact with the use of IoT and AI technologies. Then, as ICT laid the framework for contact-free purchases of products/services, contactless services were quickly implemented upon the onset of the COVID-19 outbreak to help prevent its spread. Second, the popularity of contactless services worldwide due to the pandemic fear may be a natural consequence of the fact that ICT is the foundation of the 4th Industrial Revolution (4IR) (Lee and Lee 2020a). The Global System for Mobile Communications (2020) reported that ICT will be at the center of the post-COVID-19 era as many industries have already started their digital transformation. Although digital transformation in organizations has accelerated to prevent the spread of COVID-19, some of the contactless services that existed either prior to the pandemic or were developed during the pandemic may see some major changes in the post-COVID-19 era. Still, there are opportunities for innovative new contactless services in the future. For example, studies have shown that even if people return to their pre-COVID-19 era routines, mobile applications and online platforms will grow exponentially in the post-COVID-19 era because of time efficiency, convenience, simplicity, and differentiated services that people have experienced (Bestsennyy et al., 2020; Diebner et al., 2020; Fortwengel, 2020; Fowkes et al., 2020; Kim, 2020).

2.1.1. Contactless healthcare services in the pre-COVID-19 era

In the 4IR era, the healthcare industry has implemented various innovations that have overcome the limitations associated with space and time in providing healthcare services (Lee and Lee, 2020b; Yoon et al., 2020). Advances in AI and ICBM (IoT, cloud-based ambient computing, big data, and mobile technologies) have enabled a wide-spread use of wearable devices in various forms for health monitoring and disease prevention (Yoon et al., 2020).

The use of AI in the process of healthcare treatment/diagnostic services has also been expanding. For example, "Watson for Oncology," an AI program developed by IBM, has seen extensive application as it can provide cancer diagnoses that are consistent with 90% of diagnoses made by oncology specialists (Liang et al., 2019). AI not only improves the efficiency of hospital operations management, but it also enables patient-centered healthcare services (Yoon and Lee, 2019; Yoon et al., 2020). Moreover, smart healthcare with advanced IT (e.g., AI and ICBM integrated with healthcare) is leading innovation efforts in the healthcare industry. For example, many hospitals have established smart healthcare systems where medical staff provided patients with treatment and diagnosis services both online and offline. Additionally, wearable scanners or medical devices are used for patient health management after treatment, and apps that are developed exclusively for certain hospitals can check patients' conditions 24/7. The Cleveland Clinic in the USA conducted a joint AI research with Siemens Healthineers, a leading medical technology company, to guide effective treatment of cancer patients (Cleveland Clinic News Room, 2019). The Mayo Clinic, in collaboration with Google, has redefined healthcare service delivery by establishing AI-enabled solutions to store and protect patient data, thus leading digital innovation to improve disease diagnosis and treatment (Anastasijevic, 2019).

Using AI, GE Healthcare Partners has been operating the "Clinical Command Center," a new global trend in healthcare systems, in seven hospitals across the USA, the United Kingdom, and Canada. This center increases the efficiency of hospital management and provides patient-centered healthcare services through AI-supported real-time information analysis, such as predictive prescription, machine learning, natural language processing with complex algorithms, predictive analytics, and other advanced technologies (GE Healthcare Partners website).

In the pre-COVID period, in addition to telemedicine, there were a number of contactless healthcare systems in use. One representative contactless healthcare system was for monitoring vital signs (e.g., blood pressure, heart rate, temperature, etc.) based on radio frequency identification (RFID) (Hui and Kan, 2017). While this automatic system is effective in monitoring patients' vital signs, it requires a reader devise and connectivity with other systems. Thus, this system has not seen a wide-spread application (Ukkonen and Sydanheimo, 2017). Additionally, there have been diverse applications of AI-enabled robots in the healthcare industry including assistance in inpatient rounds, preparation of medical records, reception, payment, and treatment information (e.g.., the number of patients waiting and the estimated time for examination) (Yoon et al., 2020). As aforementioned, at the dawn of 4IR smart healthcare emerged through the convergence of advanced IT, such as AI and ICBM, and this period can now be referred to as the pre-COVID-19 era (Lee and Lee, 2020, 2020b).

2.1.2. Contactless services during-COVID-19 era

The COVID-19 pandemic has demonstrated the importance of public healthcare and the need for innovative approaches to combat global pandemics. According to a report by WHO (2020a), more than a half of the countries surveyed (53%) were found to have partially or completely discontinued their regular healthcare services for hypertension, diabetes and diabetes-related complications, cancer, and cardiovascular emergencies due to COVID-19. Moreover, the study also showed that nearly 63% of the countries discontinued rehabilitation healthcare services, further highlighting how traditional face-to-face healthcare has been deeply affected by COVID-19.

In addition, during the COVID-19 pandemic, many patients preferred contactless online treatments rather than face-to-face treatments. Accordingly, telemedicine services, which are naturally contactless and widely practiced in the pre-COVID period, have expanded rapidly because they do not require direct interaction between the patient and medical staff (Bestsennyy et al., 2020; Fowkes et al., 2020; Lee and Lee, 2020b). Generally, these services encompass remote consultation through real-time phone or audio-video calls using a smartphone, tablet, or computer, and patient data can be stored on specific platforms (Bestsennyy et al., 2020; Centers for Disease Control and Prevention, 2020; Fowkes et al., 2020).

The rate of telemedicine service utilization, which was around 11% for all patients in the USA before the COVID-19 outbreak, has increased to about 46% during the pandemic, and the use of telemedicine by physicians and healthcare organizations has also expanded by 50–175 times (Bestsennyy et al., 2020). According to Minor and Bevins's (2020) interview with dean of the Stanford University School of Medicine in April 2020 (amid the COVID-19 outbreak), about 73% of all outpatients at Stanford's hospitals were being catered through telehealth visitations. During the month of February 2020 (before the COVID-19 outbreak), about 1000 virtual visits were recorded; compared to 3000 to 3500 visits at a peak day during the COVID-19 outbreak in April.

Such telemedicine services can reduce the risk of infection during the spread of an epidemic disease by delivering care through ICT while the patient practices social distancing. Telemedicine also offers other meaningful benefits by alleviating challenging problems in the healthcare industry, such as shortage of healthcare personnel, the increasing number of patients due to aging population, and long waiting times for treatment (Global Market Insights, 2020; Lee and Zafra, 2020; Lovell, 2020; Yoon et al., 2020). In May 2020, James Manyika (Co-Chair and Director of the McKinsey Global Institute) and Kevin Scott (Chief Technology Officer at Microsoft) deliberated on the use of AI in healthcare. They agreed that AI has been an effective technology in combatting COVID-19 as it can help predict, prevent, and treat COVID-19 cases. They further predicted that AI would play an even greater role in preventing contagious diseases in the future (Manyika and Scott, 2020).

During the COVID-19 pandemic, contactless services have been applied in various fields, such as telemedicine, AI-based healthcare, safety management of patients and staff (ie.g.., through mobile platforms and chatbots), and administrative work (Lee and Lee, 2020b). For example, in South Korea, patients visiting a hospital must fill out a

self-checkup questionnaire sent via a mobile app and present it at the time of appointment, and hospitals deliver employee training through video conferencing (Lee and Lee, 2020b). Today, there are various applications of contactless services available for use, such as AI for COVID-19 virus analysis, remote-controlled robots that assist in ensuring that people conform with indoor and outdoor quarantine rules, and robot-assisted disinfection of large areas during quarantine (Lee and Lee 2020, 2020b; Manyika and Scott, 2020). Recently, AITRICS, a Korean AI startup firm, is collaborating with Cleveland Clinic in the USA for deploying VitalCare, AITRICS's AI solutions platform, that can predict diseases such as Sepsis. VitalCare is expected to significantly reduce the mortality rate of patients through real-time monitoring of the patient's conditions (AITRICS, 2020). ICT had already been widely applied in the healthcare industry before the pandemic and has seen accelerated applications in a wide range of healthcare services since the outbreak.

Contactless-based telemedicine services can be characterized by three modalities that connect patients and healthcare providers (Fowkes et al., 2020). First is the remote patient monitoring system, which enables the direct and contactless transmission of a patient's clinical measurements to their healthcare providers. Second is the synchronous consultation system, which facilitates patients' interaction with healthcare providers via real-time phone or audio-video calls using physical equipment (e.g., a smartphone, tablet, or computer) (Centers for Disease Control and Prevention, 2020; Fowkes et al., 2020). Third is the asynchronous consultation system, wherein patient-related data is stored and analyzed or addressed at a later time (Fowkes et al., 2020). In summary, before the spread of COVID-19, a new digital healthcare environment was being developed with smart healthcare services, during its spread, the digital healthcare environment advanced and applications of multifarious digital devices have expanded a great deal.

2.1.3. Contactless services in the post-COVID-19 era

The capital size of the global telemedicine market was estimated at US$45.5 billion in 2019 and is expected to reach $175.5 billion by 2026 owing to growth drivers, such as the "rising cases of COVID-19 infections across the globe, increasing prevalence of chronic diseases, a growing number of smartphone users, technological advances related to mobile phones and the Internet, greater need for cost-savings in healthcare delivery, and long waiting time in hospitals for disease treatment in 2026″ (Global Market Insights, 2020). Telemedicine services have emerged as an effective healthcare delivery method during the pandemic and this trend is expected to accelerate in the future (Global Market Insights, 2020).

Still, telemedicine services must be reinforced using advanced ICT and will only become widespread when regulations are relaxed or eliminated (Lee and Zafra, 2020; Lovell, 2020). During the spread of COVID-19, many countries have implemented deregulations regarding telemedicine to minimize the gap with direct care services, thereby allowing the telemedicine market to grow. However, owing to rigid regulations on telemedicine in some countries, such as South Korea where its domestic market has not grown, propelling the continuous spread of COVID-19 (Lee and Lee, 2020b). Thus, without supportive public healthcare policies, the market for telemedicine will most likely remain static in the post-COVID-19 era. One study showed that if consumer demand for telemedicine services continues to increase in the future, accompanied by innovative ICT applications, many healthcare platform companies can grow together with preexisting companies (Yoon et al., 2020).

To ensure rapid responses to the various mutations and rapid spread of COVID-19, predictive analysis using big data and AI will become imperative (Bullock et al., 2020; Petropoulos, 2020), making ICT even more essential. Health Cluster (2020) projected that COVID-19 could become another endemic virus, implying that recurrent outbreaks will expand beyond being just a pandemic. Consequently, ICT will see even a greater role in the future for disease treatment, infectious disease prevention and analysis, and managing quarantine activities. Thus, now is the time to explore the directions and expansion of telemedicine services in the post-COVID-19 era. The major goals of this process would be effective disease treatment and prevention, effectual and timely response to the healthcare personnel shortage, and innovative approaches to creating safe healthcare environments. Achieving these goals will help lead to a post-COVID-19 era that is characterized by agile healthcare delivery systems (i.e., online and offline), flexible and expanded use of digital devices in healthcare (i.e., not only in preventing and treating diseases but also in supporting healthcare services), and healthcare services of higher quality with greater user convenience.

3. Trends of telemedicine services in select countries

In this section, we review representative cases of telemedicine services practiced in the USA, France, Japan, and China. As aforementioned, contactless services have grown exponentially during the pandemic outbreak and telemedicine applications have also accelerated.

Telemedicine services have been practiced in the US since the 1990s (Perednia and Allen, 1995). Teladoc Health, the largest telemedicine provider in the world, is a healthcare company with 2400 employees that connects doctors and patients in more than 175 countries (https://teladochealth.com/). Once patients secure health insurance that covers Teladoc services or by Teladoc's insurance, they can connect with a doctor via a video call within 10 min, using a smartphone or personal computer (PC). Doctors examine symptoms through video calls, prescribe medicines, and refer patients to specialists when needed (https://teladochealth.com/). More than 20,000 users have visited the Teladoc Health website each day during the COVID-19 outbreak (Teladoc Health, 2020).

In France, Doctolib introduced a reservation platform for French hospitals in 2013 and is now a healthcare service platform company that provides telemedicine services through an infrastructure comprising 75,000 healthcare personnel in France and Germany (Marcellin, 2019). Telemedicine consultations on this platform are possible through video calls on PCs and smartphones. Before COVID-19, approximately 1000 people were using their telemedicine services per day; however, from early March to early April 2020, the period in which COVID-19 was spreading rapidly in France, about 800,000 people used their services (Lovell, 2020).

In Japan, telemedicine services started in 2008 (Akiyama and Yoo 2016). M3 (Medicine/Media/Metamorphosis), a telemedicine information company established as a venture business in 2008 and has been operating as a specialized telemedicine company called Line Healthcare since 2019 as a joint venture with LINE, a company focused on the development of mobile applications and Internet services. M3 has 470 employees and approximately 7000 doctors working through its platform; the company provides patients with mobile app-based consultations with physicians, enabling patients to receive prescribed drugs at home (https://corporate.m3.com/en/). As of July 22, 2020 (i.e., after the COVID-19 outbreak), its market capitalization had grown from US $1.2 billion to US$32.9 billion (M3 Presentation Material, 2020).

In China, telemedicine services started with the development of an online hospital in 2014 (Wong and Li, 2020). Owing to COVID-19, the number of telemedicine service users in China is expected to reach 59 million by the end of 2020, and the telemedicine market is projected to grow to US$28 billion by 2026 (Lee and Zafra, 2020). The online healthcare company, "Ping An Good Doctor," operates an online healthcare platform that was established by Ping An Insurance, one of China's largest insurance companies. Through collaboration with 1000 in-house medical staff, 13,000 outsourced medical specialists, 3100 hospitals, and 10,000 pharmacies, the company provides various healthcare-related online services such as healthcare appointments, consultations with healthcare experts, diagnoses, and treatments. The company had 315 million users as of December 31, 2019 (Global Market Intelligence, 2020). However, from January 22 to February 6, 2020 (i.e., amid the COVID-19 outbreak in China), the number of newly registered

users rose to 1.11 billion on the Ping An Good Doctor platform, which was an increase of 10 times, and the average number of consultations per day increased by nine times since the beginning of the outbreak (Lee and Zafra, 2020; Ping An Good Doctor, 2020).

Summarily, telemedicine by its nature facilitates the shift from direct to indirect patient treatment. Nevertheless, such services require a treatment platform, a system, human resources, and various devices (PC, laptop, smartphone, webcam, etc.) to function. Still, during the COVID-19 pandemic, the number of patients who patronized telemedicine, highlighted in the above discussion, clearly indicate the effectiveness and customer satisfaction of this type of indirect healthcare. This shift in the type of desired treatment interaction (i.e., from offline to online) demonstrates the psychological state of people who desire to stay safe from COVID-19. The increasing popularity of telemedicine also reveals that people are already familiar with the notion of a digital transformation in healthcare. This trend of contactless healthcare is greatly amplified during the pandemic, not only for the traditional telemedicine but contactless healthcare delivery innovations based on advanced technologies at hospitals and care facilities.

Thus, in the post-COVID-19 period, the healthcare service trend will entail a growing interest in personal well-being that minimizes person-to-person contact due to the experience of the pandemic, desire for uninterrupted healthcare services, with persistent lack of healthcare resources due to the aging population, continuous innovations for smart healthcare on pace with the rapid developments in technologies, and lifestyle changes that focus on disease prevention rather than disease treatment.

4. Opportunities and challenges of contactless healthcare services

Contactless services emerged as an innovation for creating a competitive advantage in the 4IR age. The current COVID-19 pandemic crisis amplified the need for contact-free encounters and has become a catalyst for the growth of "untact" services (Lee and Lee, 2020b). More specifically, the rapid spread of the virus has forced governments and organizations to discourage face-to-face services in all areas, including personal lifestyles, education, work, and the manners of engagement in community activities. Previous studies suggested that organizations can remain competitive if they can decipher how various technology-based services, which were introduced with agility during the pandemic, would need to be transformed in the post-pandemic period (Zeng et al., 2020). It is imperative, therefore, for individuals, corporations, and governments to search for new opportunities of creating value and social capital while responding swiftly to the new normal in the post-COVID-19 period.

4.1. Opportunities and challenges for healthcare services

As history has shown, this pandemic will not be the last one and new ones will surely appear in the future (Jones, 2020). That means the healthcare industry, especially public health, must not only manage the current pandemic well but also be prepared for future pandemics that will most likely disrupt everything in a greater magnitude than the current one. The late Clayton M. Christensen, while being interviewed by the MIT Sloan Management Review, stated that "… the mechanics of disruption are the same as ever, but recent technological and business model innovations present unique opportunities and challenges for both incumbents and entrants" (Dillon, 2020). Accordingly, the healthcare industry is expected to encounter new opportunities and challenges in the post-COVID period.

4.1.1. Building an innovative healthcare delivery system

With the technological foundation of the 4IR era, innovative applications of digital devices have become prevalent in many industries (Yoon and Lee, 2019). In the healthcare industry, technologies such as AI and machine learning have been applied to developing vaccines and wearable devices for mitigating diseases in the early stages of their development (Manyika and Scott, 2020). In April 2020, about 73% of the patients in Stanford's hospitals had received at least one type of untact telemedicine service (Minor and Bevins, 2020). Overall, telemedicine services have grown rapidly during the pandemic as various national governments loosened regulations for telemedicine to control the spread of COVID-19.

Despite the rapid growth during the pandemic, some contactless services are likely to return to their pre-pandemic levels, depending on the service type, when effective vaccines and cures are developed (Minor and Bevins, 2020). For example, personnel recruiting would most likely return to face-to-face practices. In the healthcare system, if an examination is required due to the side effects of certain treatments or medicines, remote medical service alone may not solve the patient's problem. Nonetheless, telemedicine services are most likely to continue to grow in the future as they allow for the timely and effective delivery of healthcare services. Currently, many healthcare providers are putting great efforts into building safer environments that protect patients and medical staff from the spread of infectious diseases (Lee and Lee, 2020b). For example, with the application of face recognition and thermal imaging devices at hospital entrances, various non-face-to-face services are being provided based on mobile apps and AI-enabled robots.

In the post-COVID era, the pace of technological innovation is expected to accelerate and consumers who are familiar with the use of ICT will demand greater convenience, often involving contactless services. Thus, face-to-face and contact-free encounters should be appropriately provided through advanced technologies. For example, in the case of healthcare collaboration, a variety of operational strategies are required for value co-creation between patients and medical staff based on a one-to-many rather than a one-to-one approach (Buljac-Samardzic et al., 2020; Lee, 2019). To deliver quality healthcare services to patients, care providers should effectively leverage experiences and lessons learned before and during the pandemic (Lee and Lee, 2020b).

4.1.2. Distribution of healthcare resources through on-off-line services

Table 1 shows the trends of major healthcare indices of the

Table 1
Distribution of healthcare resources.

Healthcare indices	US	UK	Japan	SouthKorea	OECD
The percentage of healthcare expenses in GDP in 2009 to 2019	16.3% to 17.0%	10.0% to 10.3%	9.1% to 11.1%	5.8% to 8.0%	8.8% to 8.8%
The average number of practicing physicians per 1000 people in 2008 to 2018	2.4 to 2.6	2.6 to 2.8	2.1 to 2.5	1.9 to 2.4	3.2 to 3.5
The average number of nursing staff per 1000 people in 2008 to 2018	10.8 to 11.9	8.7 to 7.8	9.6 to 11.8	4.3 to 7.2	8.4 to 8.8
The average number of outpatient visits to a physician per year in 2008 to 2017	3.9 to 4	5.9 to 5	13.2 to 12.6	12.9 to 16.6	6.6 to 7.1
The average number of computed tomography scanners per 1000 people in 2008 to 2017	34.3 to 44.7	7.26 to 9.46 (in 2014)	97. to 111.5	37 to 38.2	22.8 to 26.6
The percentage of people aged 65 and over in 2007 to 2018	12.6 to 16.0	15.9 to 18.3	21.5 to 28.1	9.8 to 14.3	14.2 to 17.2
Life expectancy in 2008 to 2017	78.5 to 78.6	80.4 to 81.3	82.7 to 84.2	79.9 to 82.7	79.3 to 80.6

Source: OECD (2020).

Organization for Economic Cooperation and Development (OECD) and four member countries (USA, UK, Japan, and Korea) during about a 10-year period. Although the percentage of healthcare expenses did not change for the entire OECD group (8.8% of GDP on average, from 2009 to 2019) during the study period, the four countries all showed increases. The average number of practicing physicians and nursing staff per 1000 people also increased slightly, as the average number of computed tomography scanners per 1000 people and the life expectancy. However, the average number of outpatient visits per year decreased in the UK and Japan. An important piece of information that can be extracted from Table 1 is that the aging population will result in the increased healthcare needs, especially preventive care services. However, there exist relatively stable healthcare resources available (e.g., medical facilities, medical staff, equipment, etc.) to support the fast-increasing number of patients. Thus, there is a need to diversify care delivery systems. Many hospitals and care providers strive to improve their productivity by focusing on offline care for patients with serious care needs, while online services are delivered contact-free for patients with common sickness, long-term care needs, or preventive education (WHO, 2020b).

Combined with the continuous increasing trends of healthcare costs, visits to doctors, and the number of older people in the population, the deficiency in resources (i.e., human resources and healthcare equipment/facilities) points to the urgent need for alternatives in care delivery. If the resource shortage persists, especially in human resources, it will negatively affect future healthcare service delivery. Hence, proposing a plan to promote the efficient management of healthcare resources by integrating offline and online contact-free services, which have peaked during the COVID-19 outbreak, is important.

Future innovations for healthcare resource management are expected to rely heavily on creative applications of advanced technologies and the experiences gained during the COVID-19 pandemic. With the shared goal of controlling the spread of COVID, the sense of community has gained renewed importance, as people realize that they live in an interdependent society and the significance of collective wisdom for solidarity, fairness, and accountability, as opposed to opportunistic and individualistic behaviors (Napier et al., 2020). Community outbreaks of COVID can be prevented through collective compliance with government guidelines as well as community members' voluntary practice of civil obligations (Lee and Lee, 2020, 2020b). For instance, drive-through treatment spaces can be created to deliver care for patients with respiratory diseases, separating them from general patients.

Another reason for the increasing importance of effective management of healthcare resources is the increasing complexity of the healthcare environment (Kabene et al., 2006). In the advent of advanced digital technologies, many healthcare delivery systems have been transformed such as AI-based diagnosis, online care services, and digital medical information systems (Yoon et al., 2020). These innovations, however, brought an expanded healthcare environment, diversity in healthcare resources, and changing needs of patients. The complexity of the healthcare industry is compounded by other recent social and medical trends such as the aging population, accelerating urbanization, demand for rapid medical treatments, people's preference for preventive healthcare, the increased medical knowledge of patients, and the spread of unknown diseases (Kabene et al., 2006; Lee, 2018). As shown in Table 1, hospitals are forced to care for the increasing number of patients with limited healthcare resources in the ever-increasing environmental complexity. On the top of these complex factors, the current COVID-19 pandemic has driven many hospitals to the breaking point. Thus, contactless healthcare services represent an important strategy to effectively manage the limited healthcare resources while providing necessary patient care by overcoming spatial and time barriers.

4.1.3. Extended application of contactless healthcare services

To minimize direct in-person contacts between people to mitigate the spread of COVID-19, the online shopping and food delivery businesses have changed their service models to more "untact" models. In the education sector, from kindergarten to college levels, a large portion of service activities have moved to remote delivery modes such as online, tele-commuting, tele-education, Zoom lessons, and video conferencing (Zhou et al., 2020). Accordingly, contactless services have also increased dramatically due to the COVID-19 situation. These untact and/or distance services should be beneficial not only for the COVID mitigation efforts but also for overcoming the challenges of limited healthcare resources (Ackerman, 2019). Contactless healthcare services, including telemedicine, have become quite prevalent as many countries imposed the social distancing mandate during the pandemic period. However, there is a need for global standardization for contactless care services when they are provided across national borders due to differences in regulations, insurance coverages, and the possibility of medical errors due to cultural and language issues (Engel et al., 2014).

4.1.4. Psychological stability

During the pandemic period, it is also necessary to monitor the psychological state of COVID-19 patients and their families resulting from the trauma (Lee and Lee, 2020, 2020b). When a patient is cured, medical staff should provide collaborative treatments (e.g., psychiatric treatment and/or psychological counseling) that can help patients and their families return to their normal life patterns. Additionally, providing such supportive psychological services can help them return to their normal lifestyles more quickly (Lee and Lee, 2020b). To facilitate collaborative care, it is imperative to have close communication with the patient. When contactless healthcare is being provided to the patient, the communication method can also be contactless through virtual care, FaceTime, Zoom, or wearable devices. For example, the Virtual Care Center of Myunngji Hospital in Korea has established collaborative relationships with Korean communities in both Atlanta in the US and Guatemala to provide remote healthcare services to Korean residents (http://www.docdocdoc.co.kr). Such contactless care services provide not only treatment services but also psychological support to patients as they can communicate freely with the medical staff in their native language.

4.2. Opinions of experts on healthcare services in the post-pandemic era

To gather the experts' opinions on effective strategies for healthcare services in the post-COVID-19 era, we conducted interviews with medical staff, hospital directors, infection control managers, and general administration managers working at tertiary healthcare institutions and general hospitals in South Korea.

South Korea has been globally recognized for its effective management of the pandemic through many innovative approaches (e.g., application of advanced digital technologies for rapid testing, drive-through testing systems, mobile contact tracing apps, quarantine surveillance systems, etc.) that resulted in one of the lowest mortality rates in the world. Korea has achieved this success while maintaining a moderate level of social and economic activities without completely shutting down cities or businesses (Lee and Lee, 2020b). When COVID-19 spread at an accelerating rate, Korea was ready to implement effective strategies based on the lessons learned from its bitter experiences with SARS and MERS pandemics. Some of the innovative operational strategies that Korea has implemented have become the standard response procedures that have been adopted by many countries. Thus, in our paper, we interviewed medical experts and hospital administrators who have implemented some of the most effective strategies to battle COVID-19.

4.2.1. Interviews with medical staff at hospital A

In an interview at Hospital A, a tertiary hospital with more than 1000 beds in Seoul, medical staff (i.e., two respiratory physicians, a radiologist, and three nurses in the infection control room) predicted that the current COVID-19 pandemic would linger for years because the COVID

virus is characterized by its fast mutation rates, hindering the possibility to quickly develop effective vaccines or cures. Accordingly, they suggested the following countermeasures.

First, to ensure patient safety, untact services should be implemented in various areas that have traditionally provided face-to-face services even during the pandemic, like hospital entrance procedures and reception/payment counters for outpatients/examinations. In the case of a hospital entrance, facial recognition cameras are already being used to identify/record visitors, check fever, and ascertain the mask-wearing status. For reception and payment procedures, mobile payment services called Open Cards are being progressively implemented (Lee and Lee, 2020a). In this interview, the staff remarked that supplementary measures are needed because a large proportion of patients is senior citizens and/or physically incapable of using kiosks and/or mobile devices.

Second, the medical staff stated that telemedicine services should be bolstered due to the advantage of their contact-free encounters during and in the post-COVID-19 period. Despite the deployment of advanced ICT, the diffusion of telemedicine has been relatively slow in the healthcare sector in South Korea because of the strong opposition from doctors who run small clinics and the associations that represent their interests concerning the subjugation to larger hospitals. Nevertheless, telemedicine services should be carefully and selectively introduced while keeping in mind that patient safety is the top priority.

Third, they stated that fundamental changes are required in the design of healthcare facilities. The main issue relates to minimizing the chance of infection within the hospital while enhancing user convenience for both medical staff and patients. Such change may require the spatial separation of the traffic routes for inpatients and outpatients, patients under investigation for the virus and regular patients, measures to help avoid crowding in the waiting area, and separation between medical staff and patients.

Finally, they suggested that robots should be introduced in various areas to minimize the spread of the infection by medical staff. Robots, which are currently used to a limited extent in the logistics sector, should be used for transporting patients based on global positioning services (GPS). The medical staff also believed that hospital managers are likely to place a high priority on the implementation of robots, mainly because the hospital staff who interact directly with patients have potential to incur infection which can spread throughout the hospital and eventually lead to its complete shutdown. Summarily, in the future, minimizing the chance of infections would be the top priority of hospitals. This concern may accelerate the rapid deployment of robots in all areas of logistics, transportation (e.g., ambulance), administrative procedures, and of course care services. This trend may lead to fundamental changes in hospital design incorporating technology-enabled contactless services, telemedicine, and GPS applications.

4.2.2. Interviews with administrative staff at hospitals B, C, and D

Interviews were conducted individually with administrative staff at three hospitals. At Hospital B, a tertiary hospital in Seoul with more than 1000 beds, we interviewed the administrative director. Our interviewee at Hospital C, another tertiary hospital with over 800 beds and located about 60 miles outside of Seoul, was the infection control manager. At Hospital D, a secondary hospital located in Seoul with more than 800 beds, we interviewed the general administration manager. The major points that the interviewees raised can be summarized as follows.

First, the hospital administrators acknowledged that the COVID-19 pandemic has drastically changed daily lives of Koreans, and the healthcare community is no exception. They reported that the pandemic has brought "a new normal era," where quarantine rules are now part of people's daily lives. The interviewees also reported that when the Korean government temporarily allowed over-the-phone prescriptions and remote monitoring during the pandemic, hospitals started to offer non-face-to-face treatments. In this system, doctors would consult with their patients remotely and prescribe medications directly to the pharmacies of patients' choice or home delivery if so requested. As of April 12, 2020, a total of 3072 healthcare institutions had participated in this governmental program.

Second, the interviewees remarked that there is a lack of medical experts in infectious disease management worldwide. This deficiency in the public health has been vividly heightened with the rapid spread of COVID. For example, in Hospitals C and D, the infection control department has only 5–6 medical staff. The interviewees remarked that this was not enough personnel for handling all the tasks related to COVID-19, such as managing confirmed cases including treatment of patients, tracking and collecting information on confirmed cases, recording protocols, collaborating with other organizations, and providing guidelines for quarantine or disease prevention. They stated the need for training experts in infectious disease management at the government level. Then, when there is an infectious disease outbreak, the government can readily dispatch these experts to healthcare organizations to ensure that effective treatment and prevention protocols are promptly carried out.

Third, the interviewees stated that the development of technology for telemedicine, mobile-based smart services, and consumer-oriented services should all be accelerated through the integration of innovative technologies (e.g., robotics, big data, IoT, and cloud-based ambient computing). Additionally, they remarked that digital healthcare, an area not directly managed by medical staff, should be equipped with different forms of digital therapy products (e.g., devices, software, and mobile application software). The interviewees also remarked that the challenges of COVID-19 should be transformed into opportunities to further innovate the healthcare industry in Korea, especially government regulations in dealing with pandemics, hospital facilities that are specifically designed to treat virus patients, and medical staff development for infectious diseases (Lee and Lee 2020b). We summarize the opportunities and challenges that the pandemic has brought to the healthcare industry in Table 2.

5. Discussion

Today, online and offline services coexist, Thus, there is a need for an effective system of connectivity between these two service types, not only in the healthcare industry but also in other industries as well. For example, in the service industry, offline stores can provide opportunities for customers to experience and learn about products, while online stores can accumulate data on individual customers and build strategies by analyzing customer-specific characteristics (Lee, 2018; Lee and Lee, 2020a). The online-offline connectivity allows companies to provide customized services to customers. However, since digital detox service is also a reality to reduce people's overexposure to digital devices, it is necessary to establish a two-way strategy that reflects consumers' needs and limits. Conceptually, digital detox refers to the act of physically removing oneself from the access to and use of advanced ICT, which means resorting to an analog environment instead of a digital one (Basu, 2019). Since this type of service exists to meet specific purposes, it may also be utilized in the healthcare industry.

Along with the accelerated digital transformation in the 4IR era, the unforeseen outbreak of the COVID-19 pandemic struck the world which has hastened the deployment of untact services without much preparation. However, as social creatures, people need to interact with other humans (Aristotle [350 BC], 2000). Therefore, some of these contact-free services that have been widely used due to the pandemic may revert to their traditional face-to-face methods. Despite the challenges and opportunities brought by the pandemic, the "new normal" will begin to emerge when effective vaccines and cures for COVID-19 become widely available. The biggest risk in the post-COVID-19 era will be the uncertainty, which will be magnified with other confounding factors such as climate change, other infectious diseases, trade conflicts, and regional warfare (Poushter and Huang, 2020). As such, organizations, including healthcare providers, should be prepared for the new normal in the post-COVID-19 era.

Table 2
Opportunities and challenges in the healthcare industry.

	Opportunities	Challenges
Healthcare Industry	• Developing measures to improve the quality of the healthcare services: minimize the gap between online and offline treatments • Improving the healthcare systems to respond quickly to emergencies • Deregulating policy regarding telemedicine care • Establishing a system for real-time information sharing of patients' conditions • Improving compatibility between different digital devices • Online-offline collaboration between hospital/medical staff and patients: digitalization and channel building • Improving real-time problem solving through the use of chatbots • Promoting education and training for non-face-to-face healthcare services • Improving various contactless healthcare delivery systems for providing healthcare services • Building trust among patients and medical staff within healthcare services platform • Expanded contactless care services overseas	• Promoting accessibility to client (patient) information • Determining which method should be used to provide non-face-to-face services • The need for liability regulations for contactless services • How can the global healthcare services market expand to other industries? • How can international standardization of contactless healthcare services be promoted? • How can value creation customer experience be driven through healthcare services platform? • Promoting patients' psychological stability and safety through healthcare services platform • How can a system that promotes real-time decision making to deal with diseases be developed? • How can the promotion of social responsibility in society be provided?

This study first examined the types and backgrounds of various untact services by dividing them into three distinct periods: pre-, during-, and post-COVID-19, in order to analyze the opportunities and challenges they bring to the healthcare industry in the post-COVID-19 era. Then, we examined some representative cases of untact healthcare services in various OECD countries to identify a trend of change in the treatment methods during the pandemic. Third, to better understand the opportunities and challenges that healthcare providers will encounter in the post-COVID-19 era, we interviewed healthcare experts and administrators to explore their opinions about the effective approaches to encounter them.

6. Conclusions

The pre-COVID-19 period was characterized by the beginning stage of the expansion of various untact services and exploding applications of digital devices owing to digital transformation. Presently, we are still in the middle of the pandemic. Our hope for the post-COVID-19 era currently coexists with the constant threat of this deadly viral disease, and the current situation underpins the importance of preparing for the post-pandemic environment that requires improvements in healthcare service delivery. Even in countries that do not attach great significance on the application of advanced technologies and untact services, technology-enabled innovation has become a priority due to the COVID-19 pandemic (Kim, 2020). The suggestions we proposed (see Table 2) in this study present implications for all healthcare institutions, policy-makers, and consumers worldwide who are currently preparing for the post-COVID-19 era.

The pandemic has served as a catalyst for a radical development of 4IR in various industries. The hospital-oriented healthcare industry, which historically centered its services around diagnosis and treatment, is reinventing itself to become a consumer-oriented smart industry, which focuses on disease prevention through the utilization of advanced technologies. Accordingly, personalized smart healthcare services using ICT are becoming widely available to medical staff, patients, and the general public. These services are rapidly changing the way healthcare organizations apply digital devices, information systems, and platforms (Lee and Lee, 2020b; Liang et al., 2019; Petropoulos, 2020). Nonetheless, our study revealed that, even before the pandemic, there were many services that adopted AI in the healthcare industry for diagnosis, patient management, and organizational administration. Thus, the shift to disease prevention, health management, and telemedicine services was not a sudden event; this means that there is the need for future strategies for the expansion of untact services in the healthcare industry. Such strategies should preferably be developed from the provider-user perspective and in line with the convenience, effectiveness, and security. We believe that healthcare institutions should consider these trends when applying relevant technologies (e.g., AI, remote monitoring, blockchain, big data, and platforms). We believe developing a smart healthcare organization through the utilization of both online and offline-based smart technologies and strengthening partnerships with organizations in different sectors of the healthcare industry (e.g., pharmaceutical, insurance, healthcare devices and system development, and personal information security companies) is imperative to be prepared for the post-pandemic period.

In this paper, we reviewed the literature and cases of untact healthcare services. In addition, we collected real-world data through interviews with medical experts and hospital administrators. We carefully examined the methods used in the healthcare industry to deliver care services in both the pre-COVID-19 era and during the pandemic in order to identify possible treatment methods that should be employed in the post-COVID-19 era. We also examined, during the chaotic period of the ongoing pandemic, how the healthcare industry has been creatively providing quality service while providing prompt treatments to patients. Additionally, we explored the possibility of inter-industry convergence to enhance the capability, effectiveness, and quality of healthcare services. Overall, the untact healthcare services have exploded to mitigate the pandemic by leveraging advanced ICT technologies.

This study has some limitations. First, we categorized the time periods around the COVID-19 pandemic into pre-, during-, and post. Our categorization of the COVID-19 pandemic periods may seem premature as the world is still battling with the virus, even experiencing surge upon surge. However, in view of the rapid distribution of COVID vaccines, we do expect the pandemic will soon be controlled. We used such categorization to create a framework for the future development of operational strategies to cope with the post-COVID-19 challenges based on the current situation. Our interview data with experts in Korean hospitals is somewhat limited in scope. However, the dire situation, in the midst of the pandemic, made it extremely difficult to interview medical staff and hospital administrators. Also, while the pandemic has turned the world upside down, it has been with us for only about a year. Thus, our data from the experts represents their experience of battling the pandemic for a relatively short period of time. We do hope to gather more comprehensive data once the pandemic is under control.

Second, we discussed the telemedicine trend among select OECD countries in this study. While there was no significant increase in healthcare resources in the countries examined, there were exponential increases in the number of patients, primarily due to the aging population (see Table 1). Thus, it is logical to observe the trend of increased use of telemedicine. However, the scope of contactless healthcare services is much broader than diagnostic services through telemedicine, including such services as automatic monitoring of patients' vital signs, education programs for preventive medicine, collaborative communication with other medical personnel, patient counseling, and the like. Thus, future

research should include all possible healthcare services that can be provided through contactless method.

We believe that the framework we proposed may not be appropriate at the end of the pandemic for planning future contactless services. The third limitation of this study, therefore, is that developing operational strategies we proposed in the paper were not based on the opinions or ideas of diverse groups of experts in the healthcare industry. Future studies should base their findings based on a larger database of broader stakeholders involved in contactless healthcare services. We hope that studies on contactless healthcare services, such as this one, would stimulate future research for developing smart healthcare organizations for treating, predicting, and preventing various types of diseases, including infectious ones.

Author contributions

All authors have conceptualization, writing, and read of the manuscript. All authors have read and agreed to the published version of the manuscript.

Data availability statement

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Conflicts of Interest

The authors declare no conflict of interest.

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