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Digital Transformation Shift in Global Pharmaceutical Industry Going through the Covid-19 Pandemic Era

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Abstract With the advent of the '4th Industrial Revolution', digitalization using AI (Artificial Intelligence), big data, IoT (Internet of Things), cloud computing and mobile is accelerating across all industries and global companies have fundamentally reorganized customer experiences, business models, and operations centering on digital transformation. Business innovation drives productivity improvement, process simplification, price, competitiveness and sustainable expansion. Whether digital transformation will be necessary for the current industrial environment is no longer important, and how quickly companies achieve digitalization has emerged as the utmost crucial element in industrial continuity. As non-face-to-face and remote technologies have begun in earnest, and accelerated in the pharmaceutical industry. They are looking for ways to provide value, generate profits, improve efficiency, and sustain the future. Compared to other industries, the pharmaceutical-related sectors have shown high interest in digital transformation especially to reduce costs and meet the challenge of delivering products during the pandemic environment.

Keywords Pharmaceuticals industry, Digital transformation, AI (Artificial Intelligence) based drug discovery, Digital supply chain, Digital Therapeutics

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I. Introduction

Digital transformation entails the incorporation of digital technology across all facets of a company, fundamentally altering operational methods and customer value delivery. It also necessitates a cultural shift, demanding organizations to consistently question conventional norms, explore new avenues, and embrace the possibility of failure. The manifestation of digital transformation varies for each firm, making it challenging to establish a universally applicable definition (Table 1). But, in broad terms, we define digital transformation as the assimilation of digital technology throughout a company, resulting in fundamental operational changes and the redefinition of customer value delivery. Moreover, it demands a cultural transformation that compels organizations to continuously challenge established practices, frequently experiment, and become comfortable with the prospect of failure. This occasionally entails relinquishing longstanding business processes on which companies were founded in favor of relatively nascent methodologies that are still in the process of being defined.

Table 1. Definition of Digital Transformation

Source	Digital Transformation Definition
Brain & company	It is defined as making a change by redefining the digital enterprise industry as a digital foundation and fundamentally overturning the laws of the game
AT Kearney	It is a business activity that preemptively responds to changes in the business environment triggered by new digital technologies such as mobile, cloud, big data, artificial intelligence (AI), and Internet of Things (IoT) and pursues to dramatically increase the competitiveness of the current business or create new growth through new businesses
PWC	It is a series of processes that apply the expectations of digital consumers and ecosystems to business models and operations in business management
Microsoft	This is to devise new existing business models through intelligent systems and embrace new ways to combine people, data, and processes to create new values for customers
IBM	This is for a company to transform its business model by integrating digital and physical elements and establish a new direction for entire Industries.
IDC	This is to create new business models, products, and services based on digital capabilities according to changes in customers and markets (external environment), apply them to management, and make them sustainable
World Economic Forum	It is transforming organizations by leveraging digital technologies and business models that can improve performance

Source: The Enterprisers Project, https://enterprisersproject.com/what-is-digital-transformation

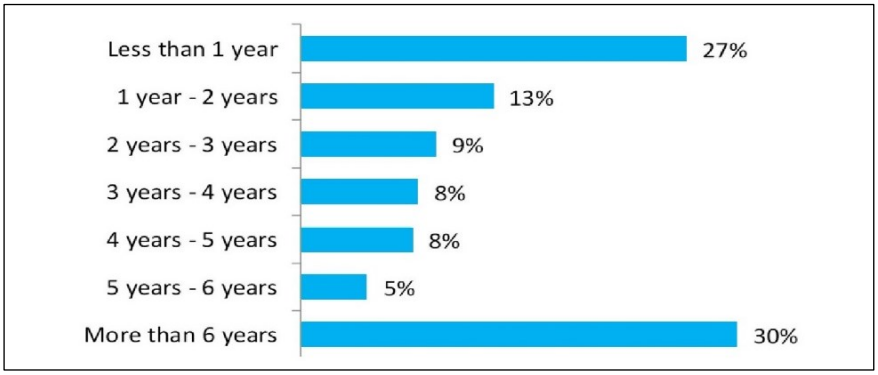
Digital transformation is revolutionizing each modern society in both developing and developed countries according to their own economic, cultural, social and technological backgrounds, presenting a range of issues and challenges. One key challenge is the digital divide, where marginalized communities and individuals lack access to digital technologies and infrastructure. This divide could deepen existing inequalities, as those without digital access are excluded from the benefits of smart city initiatives, e-governance systems, and digital services. Bridging this gap requires concerted efforts to enhance digital infrastructure, promote affordable internet connectivity, and ensure digital literacy for all. Another pressing issue is the privacy and security of residents' data. As becoming increasingly interconnected and data-driven, there is a growing concern about the collection, storage, and usage of personal information. Safeguarding privacy while harnessing the potential of data requires robust cybersecurity measures, transparent data governance frameworks, and responsible data management practices. Striking a balance between data-driven decision-making and preserving individuals' privacy rights is crucial for building trust and ensuring the ethical use of data. Furthermore, the rapid pace of digital transformation can lead to challenges in ensuring equitable access to digital services and opportunities. It is essential to address the needs of vulnerable groups, such as low-income communities, elderly individuals, and differently-abled people, who may face barriers in navigating and utilizing digital technologies. By adopting inclusive design principles and user-centric approaches, urban planners and policymakers can create digital solutions that are accessible, user-friendly, and cater to the diverse needs of various societies.

Many issues and challenges in the digital transformation era encompass bridging the digital divide, safeguarding data privacy and security, and promoting equitable access to digital services in both developing and developed countries. Addressing these challenges requires a holistic approach that considers the social, economic, and ethical implications of digital technologies in urban and rural environments. By doing so, various business industries can harness the power of digital transformation to build more inclusive, sustainable, and prosperous societies for all societies.

II. Study Backgrounds

Based on the data from Pharmaceutical-technology of GlobalData (Figure 1), it was found in a study of 100 pharmaceutical companies that over a span of 6

years, digital transformation was expedited due to COVID-19 by 30% of the companies, while more than half of the surveyed companies (51%) reported a digital transformation period exceeding 3 years. Deloitte conducted a survey involving 150 biopharma leaders to gain insights into their encounters with digital technologies and the industry's strategy towards digital innovation amidst this era of rapid change.



Source: Pharmaceutical-technology of GlobalData, https://research.aimultiple.com/digital-transformation-pharma

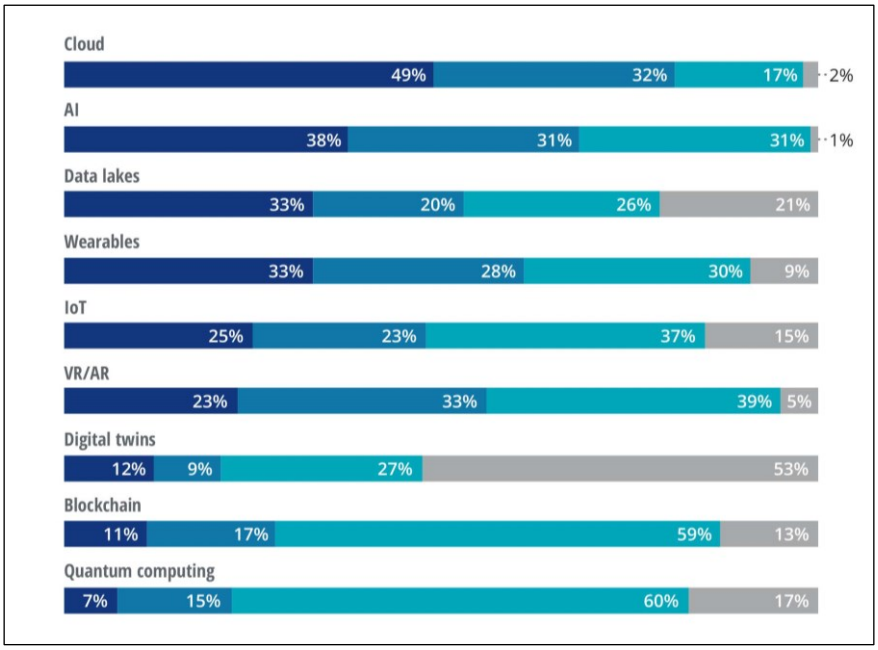
Figure 1. Covid-19's impact on the digital transformation of the pharmaceutical industry

According to Deloitte's survey (Figure 2), several digital technologies like the cloud (49%), AI (38%), data lakes (33%), and wearables (33%) have been integrated into daily operations by 150 executives from major biopharma companies (generating revenue of US$1 billion and higher) spanning the United States, Europe, and Asia. On the other hand, emerging technologies such as quantum computing and digital twins are yet to gain substantial traction.

The digital revolution in the pharmaceutical sector has been hastened by the outbreak of COVID-19, with manufacturing processes and operations not limited to leveraging pre-existing artificial intelligence and executing machining techniques solely for the identification of novel drug candidates but extending its reach to encompass the realm of clinical trials.

To find out the prediction and direction of pharmaceutical digital transformation on the time of just getting out the Covid19 pandemic era, it was reviewed with results various global research companies conducted a survey of CEOs and employees of biopharmaceutical companies focusing especially on Cold Chain Logistics, Research and Development of New Drug, and Digital

Therapeutics. Furthermore, it is intended to suggest how the pharmaceutical industry should cope with and adapt to digital transformation.



Source: Deloitte's Biopharma Digital Innovation Survey 2021

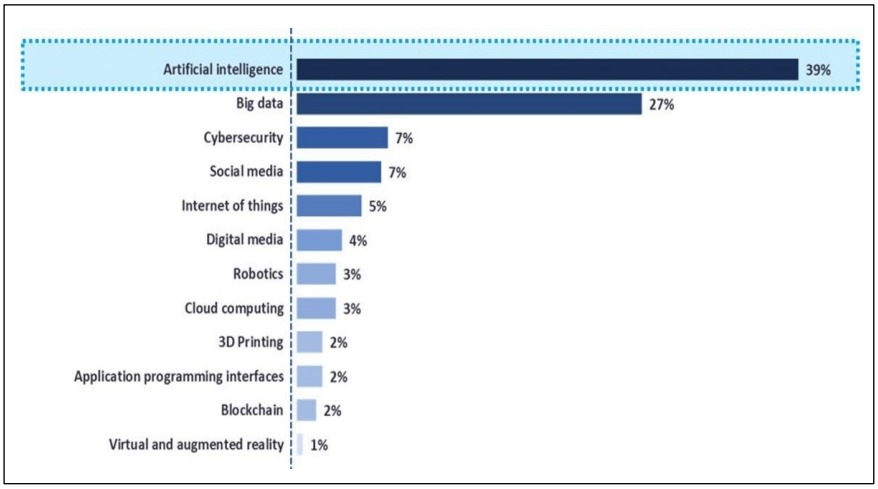
Note: These bar graphs are shown in the below four responses in different colors and ratios for the question, which of the following best describes your experience with each digital innovation technology within your organization?

Figure 2. Biopharma's experience with digital technologies

III. Methodology

While facing the impact of diverse factors like the Covid-19 pandemic, inflation, the conflict between Ukraine and Russia, and ongoing problems with the supply chain, the partnership between pharmaceutical companies and providers of emerging technologies continues to expand, particularly in the realm of research and development (R&D), offering a degree of resilience amidst geopolitical and economic upheavals. One notable emerging technology, artificial intelligence (AI), is anticipated to have a significant role in the

pharmaceutical field in 2023. According to survey data published in GlobalData's The State of the Biopharmaceutical Industry - 2023 report, 39% of healthcare industry professionals surveyed expressed their belief that AI would emerge as the most disruptive emerging technology in the sector this year (Figure 3).



Source: GlobalData, The state of The Biopharmaceuticals Industry Survey, 2023 report.

Figure 3. The Most disruptive emerging technologies in the pharmaceutical sector

AI emerges as a versatile remedy to tackle the difficulties encountered throughout the pharmaceutical value chain. To illustrate, within the realm of drug discovery and development, AI can diminish the duration required to pinpoint drug targets; in terms of the supply chain, it can augment demand prediction and inventory control; in the context of digital therapeutics, it aids in monitoring health data and accumulating or assessing health information.

1. Research and Development of New Drug

In the field of new drug development, AI, big data, cloud, and IoT are pivotal technologies that are extensively employed. By identifying potential drug candidates in the initial phases of development, thus demonstrating early-stage clinical trial success with high predictability, the overall duration and cost of new drug development can be significantly diminished. Furthermore, this approach can be employed for rare, incurable ailments where market viability is uncertain, facilitating the establishment of a treatment pathway. AI-based drug

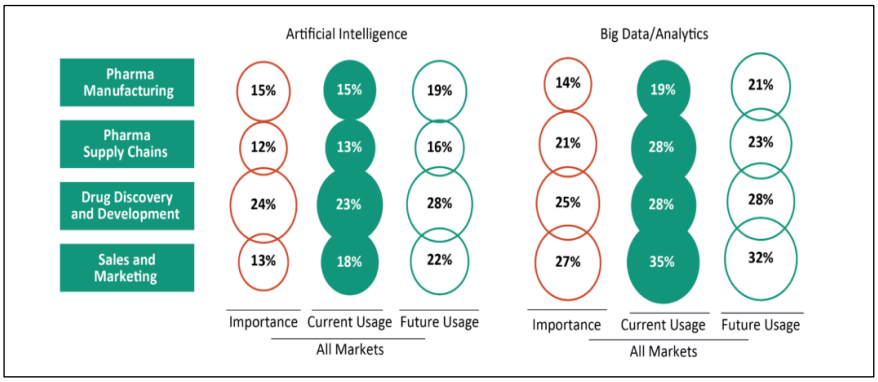
discoveries have been practically applied across pharmaceuticals, establishing AI and big data infrastructure for new drug development (Table 2).

Table 2. Artificial Intelligence (AI)-Based Drug Discovery

Pharmaceutical company	AI Company	AI Name	Technology	Indication
Merck	Atomwise	Atomet	Deep-learning screening from molecular structure data	Ebola virus infection
Novartis Pfizer Teva	IBM	Watson	Deep-learning cognitive computing technology	Cancer Respiratory & CNS disease
Santen Pharmaceuticals	Two XAR	DUMA	Deep-learning screening from literature and assay data	Glaucoma
Jassen Pharmaceuticals	Benevolent AI	Benevolent AI	Deep learning and natural language processing of research literature	Multiple
Standigm	Standigm	Standigm Best Standigm Insight	AI-based lead optimization platform AI-based hidden indication & pathway with potential target prediction	NAFLD, Parkinson's disease, autism Solid tumor
Pharos IBT	Pharos IBT	Chemiverse	Screening, analyzing and managing data library	Acute myeloid leukemia
Boryung	Pharminogen	N/A	Convolutional Deep-learning platform	N/A

Source: The Fourth Industrial Revolution and Changes of Pharmacists' Roles in the Future: 2020;30(4):217-225, Korean Journal of Clinical Pharmacy, December 31, 2020
Abbreviations: CNS, central nervous system; NAFLD, Non-alcoholic fatty liver disease; N/A, None Announced.

Artificial intelligence and big data are expected to play a significant role in the discovery and development of new drugs, as revealed by Global BigData's survey of medical professionals worldwide in 2021 (Figure 4), with respective shares of 24% and 25%. The projected growth of artificial intelligence in comparison to other areas indicates a substantial rise in its future utilization.



Source: GlobalData, Pharma Intelligence Center, Jul 15, 2021

Figure 4. Artificial intelligence and big data/analysis importance, current and future usage trends

AI and big data are also called core technologies of the 4th Industrial Revolution that are most actively introduced for drug discovery and production, disease diagnosis, clinical trials, and disease prediction in the pharmaceutical industry (Table 3). They support a faster R&D development process and enable rapid analysis of large amounts of data and disease identification to predict and respond to infectious diseases such as COVID-19 and control production through supply and demand forecasting.

Table 3. Digital transformation and its impact on global pharmaceutical companies' operations

Company	Teva pharmaceuticals	GSK	Pfizer
Type of Project	Process improvement	Process improvement and innovation	Process improvement and innovation
Business Function	Manufacturing	Research & Development (R&D)	Supply chain and logistics
Case Study	• Insilco technology for predictive biomanufacturing: • Based on computer simulation and AI	• R&D Information Platform (RDIP) • Used advanced data analytics, AI and ML	Digitized supply chain network using cloud computing
Result	• Saved experimental efforts and time • Optimized production processes	• Creation of virtual products • Smooth decision-making process for the scientists	• Complete visibility into the status of the product • Improved demand forecasting accuracy

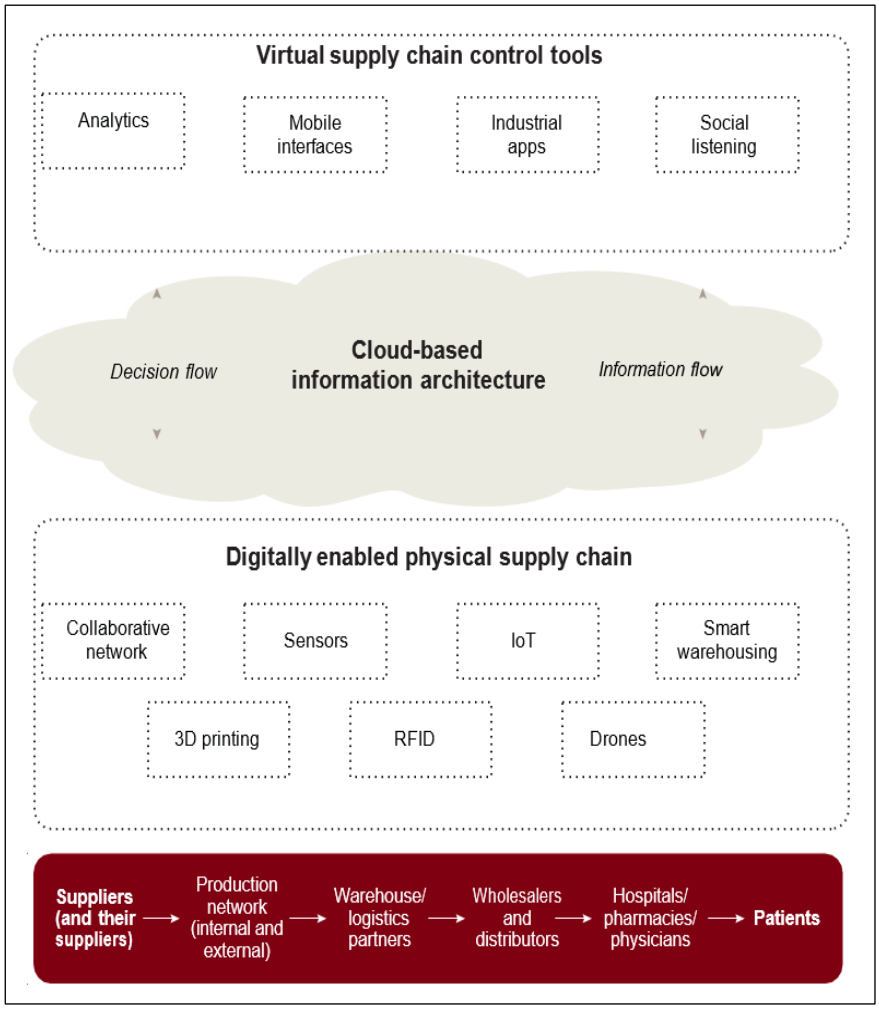
Source: Shehmir Javaid, 2021: Digital Transformation in Pharma: Technologies & Trends: AIMultiple, December 29, 2021.

Although these technologies are considered promising new techniques, there still have some limitations to overcome in the current pharmaceutical industry. The processing and analyzing of a large amount of data will affect the performance reliability in generation data models and the interpretation of complex data, as in the case of data associated with biological mechanisms, can be another obstacle to models generated.

2. Cold Chain Logistics

The Covid-19 pandemic has brought about an irreversible disruption in supply chains. It has emerged as an obstacle for pharmaceutical and healthcare logistics to an unprecedented trial, unlike any witnessed in the previous modern world. For example, it has been unveiled to the deficiency of conventional supply chain technologies like specialized packaging and refrigerated transportation, which aim to prevent drug degradation during transport. Traditional supply chains typically depend on independent systems that operate with limited or no data sharing, focusing solely on production and provision rather than customer requirements. Additionally, they lack optimization and the ability to promptly identify issues throughout the value chain. Even after identifying a problem, predicting its potential consequences and finding a solution can be time-consuming and labor-intensive. This results in production delays, reoccuring errors, and extended time-to-market, all of which can adversely impact customer satisfaction and corporate profits. Consequently, it has expedited the necessity for digital transformation to reassess all aspects, from manufacturing to distribution, igniting the comprehensive innovation of pharmaceutical and healthcare logistics. In a post-Covid-19 world, pharmaceutical supply chains must primarily consist of resilient systems and processes imbued with reliability, transparency, and intelligence, achieved by establishing a digital supply chain ecosystem.

One of the areas where digitalization has accelerated most due to COVID-19 is the biopharmaceutical cold chain. The cold chain of biopharmaceuticals refers to a logistics system for controlling drug temperature throughout the process, including production, shipment, and distribution. The digital supply chain is centered on the cloud-based information architecture, and the virtual supply chain ecosystem manages the logistics supply chain through the real-time linkage between “Virtual Supply Chain Control Tools” and “Digitally Enabled Physical Supply Chain” (Figure 5).



Source: Digitalization in pharma: Gaining an edge in operations, Strategy & analysis, PwC (2021)

Figure 5. Digital Supply Chain Ecosystem

The initial tier comprises a collection of digital instruments that offer mobile, collaborative, and dynamic interfaces for decision-making, facilitating the supply chain. Data from every component and entity within the supply chain composed of suppliers of raw materials, contract manufacturing organizations (CMOs), factories, warehouses, distributors, logistics partners, hospitals, pharmacies, physicians, and patients, undergoes processing by analytical tools accessible through computers and mobile devices. Analytical tools specific to

industries execute analyses, producing valuable insights on various operational and supply chain aspects such as orders for demand and supply, inventory levels, goods in transit, manufacturing performance at different plant, line, and machine levels, utilization, and numerous other metrics. These insights empower managers to promptly make informed decisions.

The information backbone, which constitutes the second layer, empowers the swift computation of diverse data and systems across all nodes of the supply chain. This cloud-based IT structure facilitates adaptability in physical assets and network management of supply chain collaborators, with effortless addition or removal of participants. Moreover, cloud computing overlays existing ERP systems at different nodes, ensuring seamless integration and expandability. By centralizing the collection, translation, and storage of data in the cloud, multiple databases grant universal accessibility at any given moment.

The physical supply chain, comprising various elements, facilities, production units, storage, and logistics, constitutes the third layer. These components have now embraced digitalization and function as intelligent constituents of the system, incessantly sharing real-time data through sensors, wireless transmitters, and other technologies, thereby ushering in the era of the Internet of Things within the pharmaceutical supply chain.

When these three layers converge and operate in harmonious synchronization, they give rise to cyber-physical systems, wherein humans, machines, and resources interact akin to a social network. This transformative process fundamentally revolutionizes the supply chain, shifting it from predominantly fragmented structures to truly unified supply chains. Organizations can then implement pioneering applications across all crucial facets of operational value chains, encompassing planning, sourcing, manufacturing, and delivery.

Global pharmaceutical companies and logistics companies are seeking to advance the digital transformation of logistics through cold chains based on AI, big data, IoT, and cloud technology (Table 4). Large global logistics companies that operate global pharmaceutical transportation services have already started cold chain services in Korea. But, there are only a small number of domestic logistics companies involved in the biopharmaceutical cold chain making efforts to secure the market share of the cold chain business. As a gradual establishment of professional biopharmaceutical cold chain service, digitalization is expected to improve the reliability of quality and efficiency of inventory management.

Table 4. Representative Domestic Biopharmaceutical Cold Chain Services

Company Name	Start time of cold chain service	Applied Technology	Description contents
FedEx	2010	Packaging, Material	Liquid nitrogen packaging and storage at - 70°C
		IoT, Cloud	Real-time monitoring service (SenseAware)
DHL	2012	Packaging, Material	-150°C~-30°C temperature control packaging
		IoT, Cloud	Real-time monitoring and connection to control centers for each region and country
SCL Healthcare	2014	Packaging, Material	Temperature control packaging material.
		Logistic infrastructure, Equipment	Temperature control vehicle, Temperature control container
		IoT, Cloud	Real-time monitoring of temperature, humidity, etc., with a data logger
GC (Green Cross) Cell CORPORATION	2015	Packaging, Material	Self-developed specialized packaging materials (EPP)
		IoT, Cloud	Real-time monitoring of temperature, vibration and location with RFID tags using IoT technology

Source: Digitalization Trend in the Cold Chain of Bio-Parmaceuticals, Weekly Report, P3, 2021, Industrial Technology Research Center of KDB Future Strategy Institute.

However, there could still be a limitation in case a lack of transparency and access to real-time data across segments of the cold chain may create challenges for addressing temperature excursions (e.g., How long the product was out of storage and what the temperature was at that time since each step stakeholder is monitoring in different manners then, there is no way to validate what occurs before or after handoffs).

3. Digital Therapeutics

The development of digital therapeutics was made on the basis of advanced digital technology. Digital therapeutics are disease prevention and management

technology using evidence-based advanced software (mobile applications, games, virtual reality, chatbots, and artificial intelligence). Under the law, digital therapeutics are classified as medical devices, not drugs, and are being examined and licensed. However, considering the definition of a drug, it is used for the purpose of diagnosing, treating, mitigating, or preventing people or animals and is not a machine; although digital therapeutics are close to instruments and devices, they are clearly used for the purpose of diagnosing, treating, mitigating, or preventing diseases, and used for the purpose of having a pharmacological effect on the structure and function of humans and animals. The US FDA established a patient safety net through Medical Device Safety Action Plan announced in April 2018, reflecting the industry's demand for rapid digital transformation in the pharmaceutical industry and improving the post-selling monitoring system. Making this innovative transition an integral part of healthcare systems will inevitably become a necessity. This profound transformation awaits regulators, patients, and healthcare providers to witness a paradigm shift. Moreover, substantial advancements in developmental pathways, regulations, and health technology assessment are anticipated to adapt to the value proposition of its digital revolution in conventional healthcare.

One of the key commonalities between conventional compound therapeutics and digital therapeutics is their aim to address medical conditions and improve patient outcomes. Conventional compound therapeutics typically involve the use of chemical compounds, such as small molecules or biologics, to directly target specific disease mechanisms or pathways in the body. These therapeutics are often administered orally, injected, or infused, and their efficacy and safety are evaluated through rigorous clinical trials. Digital therapeutics, on the other hand, leverage digital technologies, such as mobile applications, wearable devices, and software algorithms, to deliver interventions and treatments for various health conditions. These interventions can include behavior modification techniques, cognitive training, or real-time monitoring and feedback. Like conventional therapeutics, digital therapeutics also undergo clinical validation to ensure their effectiveness and safety.

Despite their shared objective, conventional compound therapeutics and digital therapeutics differ significantly in their mechanisms of action and mode of delivery. Conventional compound therapeutics act directly on the biological processes in the body, targeting specific molecules or receptors to modulate disease pathways. They often require absorption, distribution, metabolism, and excretion processes to reach their intended targets. Digital therapeutics, on the other hand, work through software-based interventions that leverage behavioral, psychological, or physiological principles to drive desired health outcomes. These interventions can be delivered through smartphones, tablets, or wearable

devices, allowing for real-time monitoring, data analysis, and personalized feedback. Unlike conventional therapeutics, digital therapeutics can be easily updated and adapted to individual patient needs, and they have the potential to provide continuous support and engagement outside traditional clinical settings. Both approaches have their unique advantages and can complement each other in providing comprehensive patient care. With the development of these digital technologies, the computing power related to AI calculation has increased, and the economics of installing and maintaining the system has also improved. The technical characteristics of digital therapeutics can be summarized as the convergence of biotarget + organoid + ICT + micro-robot technology. Among them, biotarget + organoid can be the existing pharmaceutical technology that determines competitiveness (Table 5).

Table 5. Commonalities and Differences between Conventional Compound Therapeutics and Digital Therapeutics

Section		Conventional compound Therapeutics	Digital Therapeutics	Remark
Commonalities		Both are approved for use in the prevention and treatment of diseases and mitigation of their symptoms based on clinically verified evidence		
	Core technology	Biotechnology + Chemistry + Pharmaceuticals	Biotechnology + ICT technology	Convergence of SW such as biotarget-organoid/ICT-virtual/augmented reality
	Mechanism of action	Chemical mechanism of action	Physical mechanism of action	Changes in pathophysiology by photoelectric, electrical, and magnetic stimuli and associative stimuli
	Effectiveness	Mostly single effect	Adjustable single or multiple effects	Optimized treatment is possible through the combination of chemical therapeutics and digital therapeutics
	Toxicity and side effects	Chemical/pharmacological toxicity, side effects, and interactions	Physical/ pharmacological toxicity and side effects	The toxicity and side effects of digital therapeutics can be designed relatively weakly or low

Differences	Dosing (medication)	• Various administration routes • Simultaneous medication of multiple drugs for multiple diseases and symptoms • Separate medication management required interaction risk	• Dosing or treatment device • Multiple treatments with one device • Real-time and continuous medication management	• Real-time management of multiple diseases and complex diseases • Elimination of concerns about interactions. • Medication management
	Patient monitoring and documentation	• A separate system is required for patient monitoring outside hospital hours •Documentation of the treatment process and a separate device is required	• Once installed, a device or program can monitor the patient's condition, etc • Automatic documentation and analysis	Through patient condition monitoring, adjustment of ongoing treatment and additional treatment is possible, and automatic documentation and analysis are also possible
	Development cost	High cost and high risk: Continuous increase in development procedures, duration, and costs.	Low cost and high efficiency: relatively low development procedures, periods, and costs	Relatively very low cost to ensure efficacy, safety, quality and stability
	Cost of use	The cost of continuous supply (dose) of chemical drugs is required	No additional cost due to the re-use of once-installed devices or programs	The initial installation cost may be high, but there is no re-use cost. As the number of doses increases, the unit price gradually decreases

Source: Korea Pharmaceutical and Bio-Pharma Manufacturers Association, Bio-Pharmaceuticals Industry in the time of paradigm shift, P22, 2021. 7. Vol. 22
Abbreviation: ICT, Information and Communication Technology

Multinational pharmaceutical companies are expanding the market through strategic alliances with technology-venture companies (Table 6). In particular, this emerging field has captured the pharmaceutical industry's interest and witnessed swift expansion in recent years, with digital transformation-focused

applications set to emerge as significant game-changers in the next decade. Moreover, the amplified scope of therapeutic advancements, utilization, and market integration grants Digital transformation a pivotal edge in enhancing patients' well-being, tackling health-related social issues, and attaining equitable healthcare

Table 6. Digital Therapeutics sharing partnerships with pharmaceutical companies

Development Company	Product	Indication	Commercialization status	Business partner	Investment partner
Pear Therapeutics	reSET	Substance use-related disorder (drug addiction)	Released	Sandoz	Novartis
	reSET-O	Opium-poisoning	Released	Sandoz	N/A
	Pear-006	Multiple sclerosis	In development	Novartis	N/A
	Unspecified	Digestive disorder	In development	Ironwood Pharmaceuticals	N/A
Welldoc	Bluestar	Type 1 and type 2 diabetes	Released	Astellas	N/A
Akili Interactive	Endeavor	ADHD	Released	Shionogi	Amgen, Merk
Nightware	Nightware	Posttraumatic stress disorder	Released	N/A	N/A
Click Therapeutics	CT-152	Major depressive disorder	Pivotal	Otsuka	Sanofu, Hikma
Cognoa	Autism Diagnostic	Autism	Pivotal	EVERSANA	N/A
Biofourmis	BiovitalsHF V1	Cardiac insufficiency	Released	Novartis	N/A
	BF140	Pain	Pilot	Chungai	N/A
Propeller Health	Propeller	Asthma, COPD	Released	AstraZeneca, GSK, Novartis, Orion, Boehringer Ingellheim	N/A
Happy Health	Happify	Multiple sclerosis-related depression and anxiety	In development	Sanofi	N/A

Sources: NPJ (Nature Partner Journals) Digital Medicine volume 3, Characteristics and challenges of the clinical pipeline of digital therapeutics, 159 (2020)
Abbreviation: N/A, Not Applicable

IV. Results

Implementing a range of digital technologies in the pharmaceutical field can enhance the production and delivery of healthcare products and maximize treatment effects in various ways. In other words, the pharma industry can reap several advantages from this transition, including enhanced drug development, improved patient engagement and healthcare, better-optimized drug research and development, improved pharmaceutical distribution, cost reduction, diminished environmental carbon footprint impact, and more heightened supply chain transparency. Here was mainly introduced the article focusing on the digital transformation of drug development, supply chain and digital therapeutics crucial when it comes to digitizing the pharmaceutical industry.

The pharmaceutical sector encounters fresh obstacles in progressively saturated and fiercely competitive markets alongside continuously evolving consumer demands. Possession of a robust medical clinical profile is no longer adequate to guarantee business prosperity. This field experiences the identical digital and retail patterns as other sectors, necessitating pharmaceutical enterprises to acquire the skills of not only introducing and advertising their offerings but also crafting and overseeing digital and hybrid experiences.

In the R&D of new drugs and digital therapeutics, digital transformation has been introduced and utilized especially in new drug development and simplified clinical trials looking forward to reducing their cost and time by shortening the development period. Digital therapeutics are recognized for their treatment effects, which are considered generic medicines beyond the characteristics of existing medical devices. They are very expected to bring out various therapeutic effects that could not have been achieved over the previous traditional drug development and therapeutics.

Insights gained from the Covid-19 pandemic have led to increased efforts by pharmaceutical companies to tackle the issue of the supply chain. The integration of digital advancements into pharmaceutical manufacturing could have the potential to bolster the supply chain, enhance drug development, and streamline therapeutic remedies, effectively minimizing possible disruptions in advance. Through real-time monitoring, digital technologies can offer proactive and efficient means of identifying optimal solutions. In addition, the most

optimal delivery system between the supplier and the end consumer could be provided by intensively collecting and analyzing information based on the cloud-based information architecture.

V. Discussion

For the past 10 years, corporate-level efforts for digital transformation have been made in all industries, and this was due to the rapid advancement of cloud, IoT, AI, and big data technologies, which are the digital core technologies representing the 4th industrial revolution. New approaches based on digital transformation are actively being introduced for the efficiency and continuity of business within industries in the establishment of business models, corporate operation processes, logistics, and R&D.

There is no denying that manufacturing has undergone a significant digital transformation, becoming faster, more streamlined, and highly automated. Nonetheless, the pharmaceutical sector is relatively inexperienced in the realm of digital innovation. Numerous pharmaceutical manufacturing leaders may lack comprehension regarding the underlying mechanisms of cutting-edge advancements, such as Machine Learning, Artificial Intelligence, Process Automation, Advanced Data Analytics, and Cloud Computing. This deficiency in firsthand knowledge can impede progress, but it should not serve as a deterrent to embracing digital transformation in its entirety. Additionally, there exist institutional constraints that hinder the expansion of opportunities for digital transformation within the pharmaceutical industry. Specifically, the domains of new digital therapeutics must expeditiously establish legal and regulatory frameworks that keep pace with the rapidity of digital transformation.

VI. Conclusion

Digital transformation in the pharmaceutical industry has led to active collaboration between companies in the IT industry and pharmaceutical companies, which were classified as completely different industries. Digital transformation within the industry is expected to determine the future competitiveness of a company by having a high positive effect on the establishment of a new business model, production through prediction, prediction of risk factors, and increase in the success rate of new drug development.

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