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Metaverse in the Healthcare – More Real than imagined!

Aman Bahl, Syneos Health®

ABSTRACT

The metaverse is a term used to describe a collective virtual shared space created by the convergence of physical and virtual worlds. In healthcare, the metaverse can be a virtual space where healthcare professionals and patients can interact, exchange information, and collaborate on treatments and research.

Healthcare professionals can use the metaverse to simulate medical procedures and surgeries, collaborate on research and development, and engage in virtual medical training and education. The metaverse can also provide a platform for medical conferences and events, enabling professionals to connect and share knowledge and expertise from around the world.

Overall, the metaverse has the potential to revolutionize healthcare by providing more accessible and personalized care, improving the efficiency and effectiveness of medical treatments, and fostering greater collaboration and innovation among healthcare professionals.

INTRODUCTION

The concept of the metaverse in healthcare is becoming more real than imagined. With the increasing use of virtual and augmented reality technologies, healthcare professionals are exploring the potential of the metaverse to improve patient care, research, and education.

In healthcare, the metaverse can offer several benefits. Patients can access virtual consultations, remote health monitoring, and virtual support groups from the comfort of their own homes. Healthcare professionals can use the metaverse to simulate medical procedures, collaborate on research and development, and engage in virtual medical training and education.

Some key applications of metaverse in healthcare are mentioned in the figure 1 below and briefly explained.

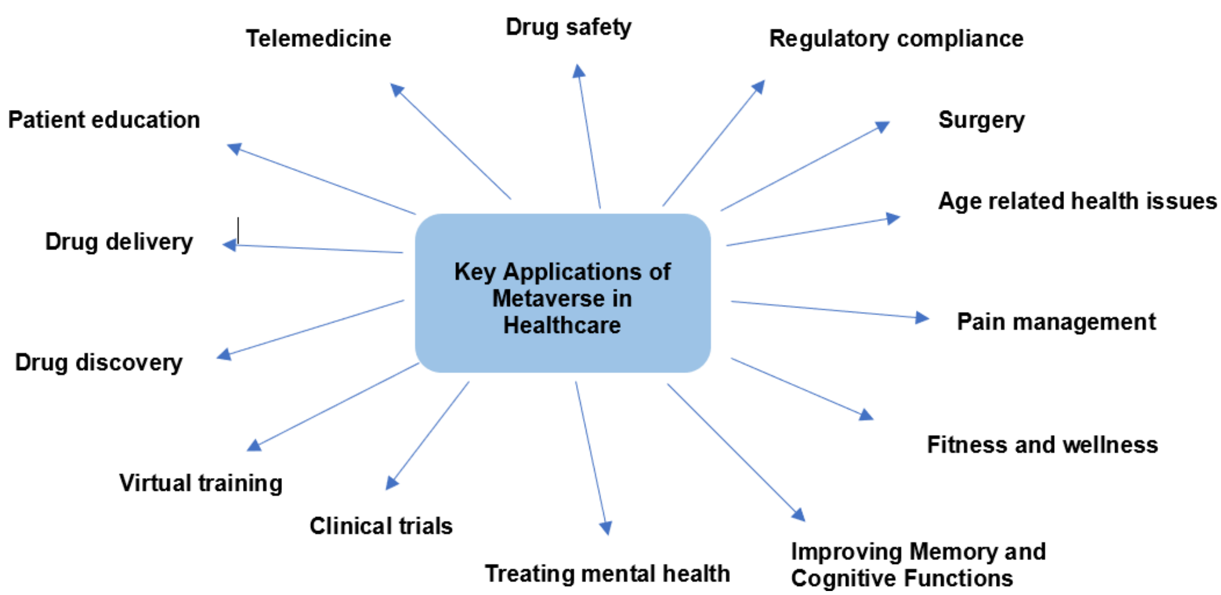

Figure 1: Key applications of metaverse in healthcare

Surgery

Metaverse reduces the time to perform surgeries by allowing surgeons to plan out surgical approaches ahead of the procedure. Surgeries using such technologies are also performed by robotic devices controlled by surgeons (who are present at a remote location), which improve procedural accuracy and reduce the associated risks and complications. Some actual use cases are:

Johns Hopkins neurosurgeons have performed the institution's first augmented reality surgeries in living patients [Ref:1]

George Washington university adopted an advanced virtual reality tool for neurosurgery, where surgeons could virtually examine a patient's brain and body ahead of the operation [Ref:2]

AccuVein is really a cutting-edge vein imaging system that eliminates the fear of bruising after an injection procedure [Ref:3]

Age related health issues

Some hospitals are also using virtual reality (VR) simulations to help doctors better understand what their patients are going through. VR can simulate health conditions for ailments such as dementia, parkinson's disease, or a migraine headache.

For additional details on the role of the metaverse in an aging population, refer to publication [Ref:4]

Pain management

VR applications can also be used to help women in labor, patients suffering from acute and chronic pain, and more. Often, virtual reality treatment can reduce or remove the need for pharmaceutical therapies.

VR headsets are also being used to help sick and injured children deal with treatments by providing an escape into digital worlds and games. By distracting them from their pain and anxiety, VR reduces the amount of pain and anxiety that is experienced by patients. Some actual use cases are:

Companies like Alameda-based KindVR are using virtual reality programs to soothe pediatric patients before an MRI and calm them before an operation [Ref:5]

In November 2021, the U.S. Food and Drug Administration authorized marketing of EaseVRx developed by AppliedVR, a prescription-use immersive virtual reality (VR) system that uses cognitive behavioral therapy and other behavioral methods to help with pain reduction in patients 18 years of age and older with diagnosed chronic lower back pain.[Ref:6]

Fitness and Wellness

For patients in need of physical rehabilitation, VR has been shown to be an effective tool in treatments. In children with cerebral palsy, VR has also been found to be a useful treatment method that can significantly improve motor functions. Some actual use cases are:

HealthLand.io, aims to address people's mental and physical wellness needs by allowing fitness trainers as well as health experts to open their own online fitness club in the HealthLand metaverse, where people can join and receive low-cost health consultations and fitness training from the comfort of their own homes. [Ref:7]

Companies such as XRHealth have been working on utilizing VR technology for physical and occupational therapy purposes. [Ref:8]

Improving Memory and Cognitive Functions

Companies like MyndVR and Rendever are using VR technology to help seniors improve their memory and cognitive function, rehab therapy, and socialization [Ref:9] [Ref:10]. Studies have shown that VR intervention can improve cognitive and motor function in older adults with mild cognitive impairment or dementia, especially in attention and execution, member, global cognition, and balance.

To understand the future applications of metaverse in cognitive decline, refer [Ref:11]

Treating Mental Health

The metaverse could be used to provide virtual therapy and counseling services for mental health patients, providing them with a safe and immersive environment to explore their thoughts and emotions.

Patients can use VR to address anxiety and trauma. For example, a psychologist can treat a patient traumatized by a car crash through virtual exposure therapy to public streets, a safer environment for a patient than an in-person visit. Its effectiveness is often dramatic; The same kind of treatment can also be used to help patients suffering from other psychological ailments and phobias, including depression, post-traumatic stress disorder, and more. Following are some actual use cases:

Bump Galaxy uses the gaming environment and mechanics to facilitate therapy. It blurs the lines between care giver and care receiver, framing playing as caring. [Ref:12]

EndeavorRx is an FDA-authorized prescription digital therapeutic that targets cognitive processes involved in attention function for kids. [Ref:13]

Some of the other key applications of Metaverse in healthcare are:

Clinical trials: The metaverse has the potential to transform clinical trials by providing a virtual environment for patients to participate in trials, reducing the need for in-person visits and making it easier to recruit patients from around the world. The metaverse could also provide a more immersive and engaging experience for patients, leading to improved trial adherence and outcomes.

Virtual training: The metaverse could be used to provide virtual training and education for healthcare professionals, including virtual simulations of medical procedures and surgeries. This could improve the quality of training and reduce the need for expensive equipment and facilities.

Drug discovery: Metaverse can be used to design and discover new drugs by simulating molecular structures, chemical properties, and biological characteristics of potential candidates. The metaverse could provide a virtual environment for drug development and research, allowing researchers to simulate drug interactions and conduct virtual experiments. This could reduce the time and cost of drug development and lead to faster approvals for new treatments.

Drug delivery: Metaverse can be used for the safe and efficient delivery of drugs by creating virtual models of the human body and testing the effectiveness of various delivery methods.

Patient education: Metaverse can be used to educate patients about the proper use and dosage of medications, potential side effects, and drug interactions.

Patient engagement: The metaverse could provide a new way for pharmaceutical companies to engage with patients, providing a more immersive and interactive experience than traditional marketing and educational materials.

Data visualization: The metaverse could be used to visualize complex medical data, such as genomics or clinical trial data, in an interactive and immersive way. This could help researchers and healthcare professionals better understand and analyze data, leading to improved patient outcomes.

Telemedicine: Metaverse technology can be used to facilitate remote patient monitoring and teleconsultations between doctors and patients in real-time. The metaverse could provide a virtual platform for telemedicine and virtual healthcare services, allowing patients to consult with healthcare providers remotely and access healthcare services from anywhere in the world.

Drug safety: Metaverse can be used to predict and anticipate potential risks associated with drugs, including adverse reactions, toxicity, and drug interactions.

Regulatory compliance: Metaverse can be used to ensure regulatory compliance by providing a secure and transparent platform for data-sharing and monitoring drug development and delivery processes.

Pfizer has teamed up with digital training company Gronstedt Group to bring virtual reality (VR) simulations to investigative sites as a way of improving compliance with clinical trial protocols, including the way study drugs get compounded. [Ref:14]

TECHNOLOGY USE IN METAVERSE

Technology plays a critical role in the development and use of the metaverse. Here are some of the ways that technology is used in the metaverse:

Virtual Reality (VR): One of the most significant technologies used in the metaverse is VR. With VR technology, users can immerse themselves in a completely virtual environment and interact with it as if it were real.

Augmented Reality (AR): AR is another technology that is often used in the metaverse. AR overlays virtual content on top of the real world, creating a mixed reality experience. This technology is particularly useful for creating interactive experiences in physical locations.

Blockchain: The use of blockchain technology is also becoming increasingly popular in the metaverse. Blockchain allows for the creation of secure, decentralized virtual environments that can be used for everything from gaming to socializing.

Artificial Intelligence (AI): AI is often used in the metaverse to create intelligent, lifelike characters and NPCs (non-player characters) that can interact with users in realistic ways.

Cloud Computing: The metaverse requires a massive amount of computing power to operate, which is why cloud computing is an essential technology. Cloud computing allows for the creation of scalable, distributed virtual environments that can be accessed from anywhere.

Overall, technology plays a crucial role in the development and use of the metaverse, and new technologies are likely to emerge as the metaverse continues to evolve.

Metaverse involves the convergence of three major technological trends, which all have the potential to impact healthcare individually. Together, though, they could create entirely new channels for delivering care that have the potential to lower costs and vastly improve patient outcomes. These are telepresence (allowing people to be together virtually, even while we are apart physically), digital twinning, and blockchain as shown in figure 2 below.

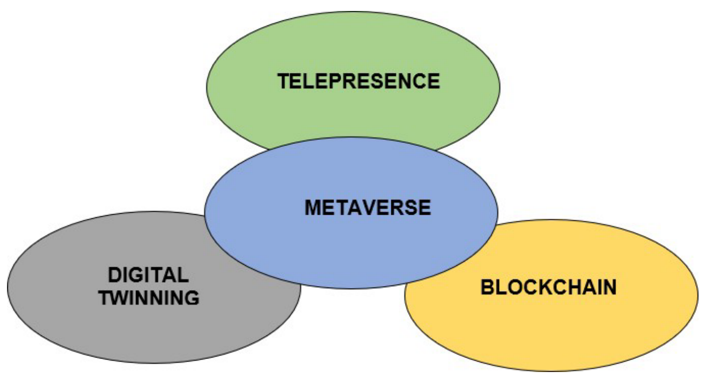

Figure 2: Convergence of three major technological trends

We have already discussed telepresence and will be discussing the other two technological trends digital twinning and blockchain below.

DIGITAL TWINNING

Digital twin refers to a virtual replica of a physical object, process, or system that uses data and simulation to reflect the behavior of its physical counterpart. In healthcare, the concept of digital twin has been applied to create a digital representation of a patient's physiological system, allowing clinicians to monitor their condition in real-time and predict the response to treatments.

Digital twin technology also enables physicians to test different treatment strategies and predict outcomes without involving the patient in extensive and expensive clinical trials. This approach could help to accelerate the development of new drugs and therapies, reducing the time and costs associated with clinical research.

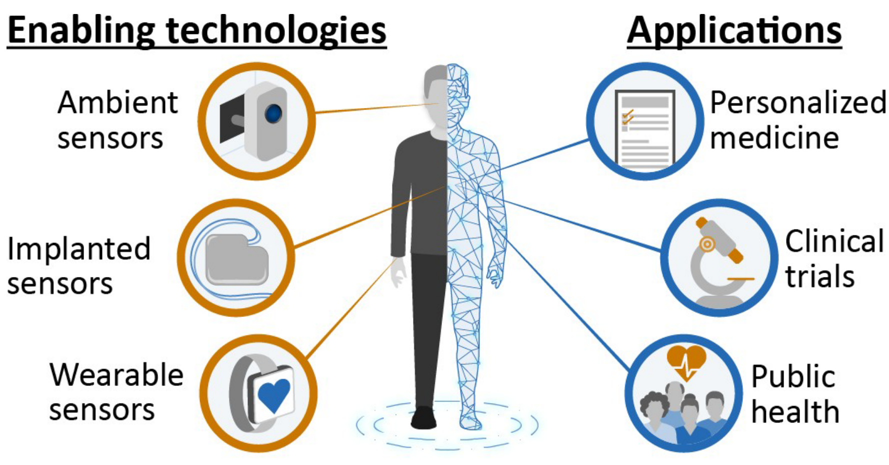

Figure 3. Examples of how digital twins can be used in health care [Source:15]

Digital twin technology in healthcare refers to a virtual model of a patient's physical health that can be used to understand the potential effects of various treatments and interventions on that patient's health. Data from different sources, including wearable devices; electronic health records; and data from MRI, PET scans, and CT scans, can be integrated in a patient's digital twin to offer a more inclusive view of their health. This can assist healthcare professionals to understand, monitor, and manage patients' health more effectively as shown in figure 3 above.

DIGITAL TWIN TECHNOLOGY APPLICATIONS

Digital twin technology has many potential applications in the pharmaceutical industry, including:

Drug development and discovery: Digital twin technology can be used to simulate the properties and behavior of molecules and drugs during the development process. This helps to identify potential issues early in the development process, such as interactions with other drugs, toxicity, or stability.

Clinical trials: Digital twins can be used to create virtual patient cohorts for clinical trials. This allows researchers to test the safety and efficacy of drugs in a simulated environment, reducing the need for actual human testing.

Manufacturing process: Digital twins can be used to simulate and optimize the manufacturing process of drugs, including quality control and equipment monitoring. This can lead to improved efficiency, lower costs, and better product quality.

Quality control: Digital twin models can help detect and prevent quality issues in pharmaceutical products by monitoring and analyzing process data in real-time, allowing for early identification of potential defects.

Predictive maintenance: Digital twin models can help predict when pharmaceutical manufacturing equipment is likely to fail, allowing for proactive maintenance and reducing downtime.

Supply chain optimization: Digital twin models can be used to optimize pharmaceutical supply chain operations, including inventory management, transportation, and distribution.

Continuous monitoring: Digital twins can be used to monitor the health of patients in real-time. This allows doctors to detect any potential issues early and optimize treatment plans based on individual patient characteristics.

Personalized medicine: Digital twin technology can be used to create personalized models of patients, based on their genetics, medical history, and lifestyle factors. These models can be used to simulate potential treatment options, allowing doctors to tailor treatments for individual patients.

Overall, digital twin technology has the potential to improve the efficiency, quality, and safety of pharmaceutical manufacturing and drug development processes, ultimately leading to better healthcare outcomes for patients.

FUNDAMENTAL TECHNOLOGIES THAT ENABLE DIGITAL TWINS

The fundamental technologies that enable digital twins in the pharmaceutical industry are shown in the figure 4 and explained below:

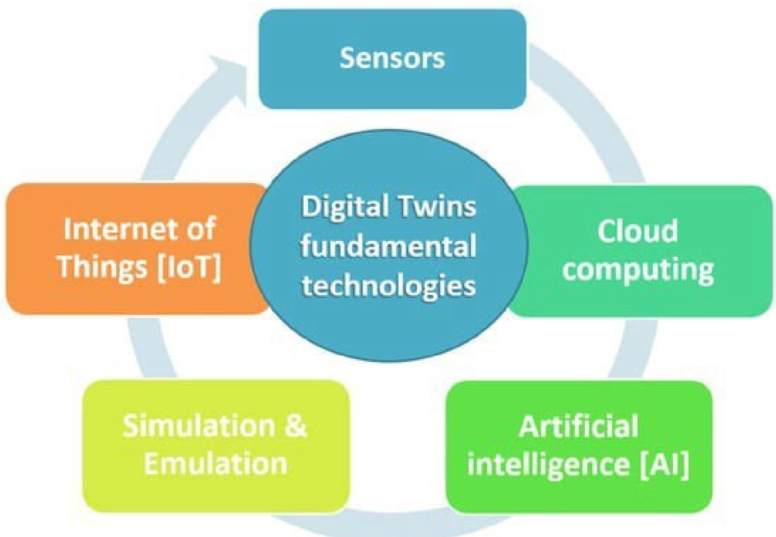

Figure 4. Digital twin fundamental technologies. [Ref:16]

Data analytics: Digital twins rely on large amounts of data from various sources, including manufacturing equipment, clinical trials, and patient health records. Advanced analytics techniques, such as machine learning and artificial intelligence, are used to extract insights from this data and generate predictive models.

Internet of Things (IoT): IoT devices, such as sensors and cameras, are used to collect data in real-time from manufacturing equipment and other sources, providing the input needed for digital twin models.

Cloud computing: Digital twin models require significant computing power and storage, which can be provided through cloud computing platforms.

Simulation software: Digital twin models use simulation software to create virtual replicas of physical systems, allowing for testing and optimization of manufacturing processes and drug development.

Augmented reality and virtual reality: These technologies can be used to visualize and interact with digital twin models, providing a more immersive experience for pharmaceutical personnel.

Overall, digital twins rely on a combination of data analytics, IoT, cloud computing, simulation software, and visualization technologies to create virtual replicas of physical systems in the pharmaceutical industry.

DIGITAL TWINS PROCESS FLOW DIAGRAM IN METAVERSE

The process flow diagram for digital twins in the metaverse can be summarized in figure 5 below:

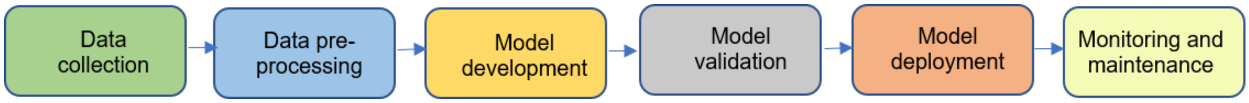

Figure 5: Process flow diagram for digital twins in the metaverse

Data collection: Data is collected from various sources, such as manufacturing equipment sensors, clinical trials, and patient health records, and stored in a centralized database.

Data pre-processing: The collected data is pre-processed to remove noise, outliers, and other errors, and to convert it into a format suitable for analysis and modeling.

Model development: Digital twin models are developed using advanced analytics techniques, such as machine learning and artificial intelligence, and simulation software. The models replicate the behavior of physical systems, such as drug development processes, manufacturing equipment, and clinical trials.

Model validation: The digital twin models are validated using real-world data, ensuring that they accurately represent the behavior of the physical systems they are modeling.

Model deployment: The digital twin models are deployed in the metaverse, providing virtual replicas of physical systems that can be interacted with in real-time. This allows for testing and optimization of manufacturing processes, drug development, and clinical trials.

Monitoring and maintenance: The digital twin models are continuously monitored for accuracy and updated as needed to reflect changes in the physical systems they are modeling. This ensures that the virtual replicas remain representative of their physical counterparts.

Overall, the process flow diagram for digital twins in the metaverse in pharmaceuticals involves collecting and processing data, developing, and validating digital twin models, deploying them in the metaverse, and monitoring and maintaining their accuracy over time. This allows for virtual testing and optimization of physical systems, leading to improved efficiency, quality, and safety in the pharmaceutical industry.

BENEFITS OF DIGITAL TWINS IN HEALTHCARE

Digital twins can run any number of useful simulations to study multiple processes. Using a digital twin would allow the experiment or trial to be run and studied much more quickly and safely.

Digital twins of hospitals

By creating a digital twin of a hospital with healthcare data integration and, hospital administrators, doctors, and nurses can get powerful, real-time insight into patient health and workflows, and clinical decision support. Using sensors to monitor patients and coordinate equipment and staff, digital twins offer a better way of analyzing processes and alerting the right people at the right time when immediate action is needed.

Few benefits of Digital twins of hospitals are:

Resource optimization: Leveraging historical and real-time data of hospital operations and surrounding environment (e.g., COVID-19 cases, car crashes, etc.) to create digital twins enables hospital management to detect bed shortages, optimize staff schedules, and help operate rooms. Such information increases the efficiency of resources and optimized the hospital's and staff's performance, while decreasing costs.

Risk management: Digital twins provide a safe environment to test the changes in system performance (staff numbers, operation room vacancies, device maintenance, etc.) which enables implementing data-driven strategic decisions in a complex and sensitive environment.

One hospital measured a 900 percent improvement in cost savings after implementing digital twin technology to remove bottlenecks in patient flow. [Ref:17]

Moreover, digital twins can predict and prevent patient emergencies like cardiopulmonary or respiratory arrest, known as code blues emergencies, resulting in more lives saved. In fact, one health care network that implemented digital twin technology in their hospitals saw a 61 percent reduction in code blue events [Ref:18]

Digital twin of the human body

Digital twins are also applied for modeling organs and single cells or an individual's genetic makeup, physiological characteristics, and lifestyle habits to create personalized medicine and treatment plans. These replicas of the human body's internal systems improve medical care and patient treatment by:

Personalized diagnosis: Digital twins allow collection and usage of vital data (e.g. blood pressure, oxygen levels, etc.) at the individual level which helps individuals to track persistent conditions and, consequently, their priorities and interactions with doctors by providing basic information. Thus, such personalized data serve as the basis of clinical trials and research data at labs.

One of the centers specialized on personalized medicine is Linköping University in Sweden who mapped mice RNA into a digital twin to predict the effects of medication. [Ref:19]

Treatment Planning: With advanced modeling of the human body, doctors discover the pathology before the disorders are evident, experiment with treatments, and improve preparation for surgeries.

OPUM has released the Digital Knee® clinical data standard that builds a digital representation, or twin, of a patient's knee. The standard is focused on data collection outside of the clinic to deliver a continuous holistic picture of a patient's knee health [Ref:20]

Digital twins for medicine and device development

Digital twin in healthcare can improve the design, development, testing, and monitoring of new drugs and medical devices. For example:

Drugs: Digital twins of drugs and chemical substances enable scientists to modify or redesign drugs considering particle size and composition characteristics to improve delivery efficiency.

Devices: A digital twins of a medical device enables developers to test the characteristics or uses of a device, make alterations in design or materials, and test the success or failure of the modifications in a virtual environment before manufacturing. This significantly reduces the costs of failures and enhances the performance and safety of the final product.

In 2021, GSK announced a successful proof-of-concept of a digital twin approach for vaccine manufacturing with Siemens and Atos, which uses machine learning (ML) and modelling to provide new insights for optimizing the development and manufacturing of vaccines. [Ref:21]

In 2022, Sanofi struck a deal to use Dassault's 'Made to Cure for BioPharma' industry solution experience based on the 3DEXPERIENCE platform to design, implement, qualify, and operate modular production lines at its two "Evolutive" facilities in France and Singapore. [Ref:22]

With the help of virtual reality (VR) technologies, Pfizer is creating a $450 million sterile injectables factory, with a "virtual factory" component that will harness digital twin technology to optimize the supply chain as well as train employees in a more efficient way. [Ref:23]

The Living Heart project is an example of digital twins in life sciences. In this project, the FDA, leading cardiovascular researchers, medical device manufacturers, practicing cardiologists, and educators are involved in the analysis of blood circulations and visualization of the anatomy to develop devices faster [Ref:24]

BLOCKCHAIN

The blockchain technology can bring significant benefits to the pharmaceutical industry by reducing supply chain inefficiencies, preventing counterfeit drugs, improving clinical trial data management, and ensuring regulatory compliance. The way our healthcare data is currently stored makes it extremely difficult to transfer the data from clinician to clinician or physician's office to physician's office. Blockchain is a more efficient way of storing and transferring healthcare data securely. It can provide patients with control of their own records and allow them to grant access remotely with ease.

Some of the key applications of blockchain in healthcare are shown in figure 6 below.

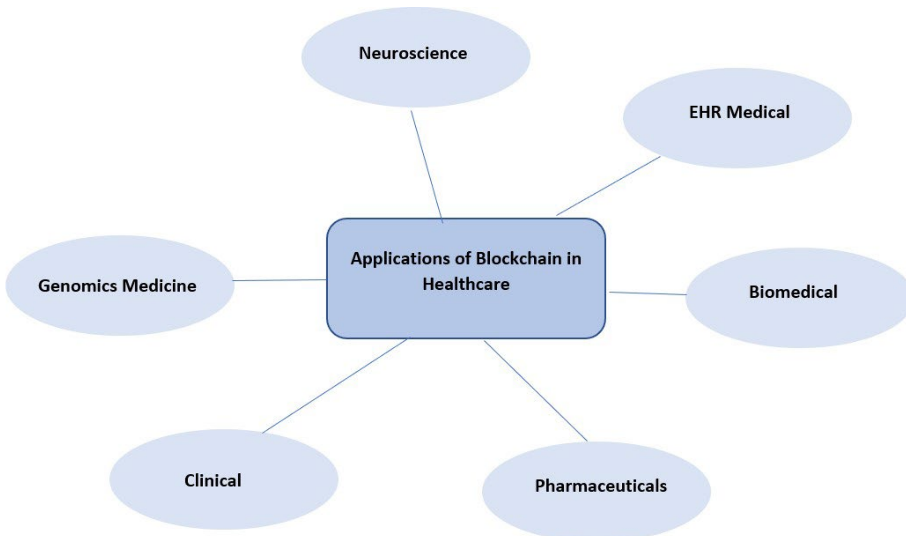

Figure 6: Key applications of blockchain in healthcare

Some promising use cases for blockchain in healthcare are as follows:

Medical record management: Medical records can be safely stored and managed using blockchain, improving accessibility for patients and healthcare professionals. Patients' ability to control access to their medical records enhances security and privacy. One example is MedRec, a blockchain-based system for managing medical information created by MIT researchers [Ref:25]

Clinical trials: Clinical trials require massive amounts of data, which can be challenging to manage, analyze and verify. Blockchain can help manage and verify clinical trial data by providing secure and decentralized storage for health data, ensuring that sensitive patient information is kept private and protected. The Clinical Trials Reporting and Results (CTRR) platform is one example of a platform using blockchain to store clinical trial data. [Ref:26]

Prescription drug traceability: Blockchain technology can trace prescription medications from the point of manufacture to the final customer, lowering the chance that fake medicines will enter the supply chain. An example is a blockchain-based network called MediLedger, which tracks the flow of prescription medications [Ref:27]

Recently, IBM announced that it is working with KPMG, Merck and Walmart to develop a pharmaceutical blockchain platform that can track drugs as they move through the global supply chain. [Ref:28]

Supply chain management: One of the crucial issues in the pharmaceutical industry is the transparency of the supply chain. Using blockchain, organizations can create a tamper-proof digital ledger that tracks the entire lifecycle of medicines - from production, distribution, and transportation to pharmacies and finally the end consumers. The transparency and traceability provided by blockchain can help eliminate waste, fraud, and errors in the supply chain.

A blockchain-based supply chain management system utilized in the pharmaceutical industry is VeChain, for example [Ref:29]

Medical device management: Blockchain technology can safely manage medical device data, including usage statistics and upkeep logs, enhancing patient safety and lowering the likelihood of faults. For example, chronicled is a platform for managing medical devices based on the blockchain [Ref:30]

Telemedicine: Telemedicine data, including video consultations and electronic prescriptions, can be safely stored, and shared via blockchain, enhancing patient access to care. An example of this use case is the blockchain-based telemedicine platform Solve.Care [Ref:31]

Drug development: With blockchain, drug development can be more transparent and efficient, enabling researchers to share information and work together more successfully. The Clinical Research Blockchain platform is one example of a blockchain-based system for storing and exchanging clinical research data [Ref:32]

Personalized medicine: Genomic data may be safely stored and shared using blockchain, enabling more individualized and efficient medical treatments. Shivom, a platform for exchanging and interpreting genetic data, is an example [Ref:33]

Health insurance: Blockchain can be applied to the processing of health insurance claims to increase transparency, efficiency and speed while decreasing fraud. For instance, MetLife is using blockchain to streamline the life insurance claims process, reducing the time required to process claims and improving the overall customer experience [Ref:34]

Regulators and compliance: Regulators such as the Food and Drug Administration (FDA) are often tasked with ensuring that drugs comply with the required standards. Blockchain can be used to create a digital ledger of critical drug information, including manufacturing, and distribution information. This would allow regulators to easily identify any anomalies or discrepancies in the drug's supply chain and ensure compliance.

Blockchain can completely change the healthcare sector from medical record management to drug discovery and health insurance. Even though these use cases are still in the early stages of research, they have the potential to boost healthcare delivery effectiveness and improve patient outcomes.

FOOD AND DRUG AUTHORITY (FDA) AND METAVERSE

FDA appears to be approaching this new frontier with an open mind. It has already begun working on potential regulations for the use of the metaverse in drug development and for therapies using metaverse simulations. For example, FDA has shown a willingness to implement computer-aided simulations in the drug development process through its model-informed drug development (MIDD) pilot program. Additionally, FDA recently requested public comment on medical devices with metaverse technologies.

The agency has also entered a partnership with Siemens regarding digital twins in medical device development. FDA provided fundings to Siemens for a pilot program to show how digital twins could improve product quality, development, and commercialization. While the current pilot program with FDA is focused on medical devices, Siemens aims to demonstrate how digital twins could also be used for biologics and pharmaceuticals. The project is also likely to assist FDA to improve industry guidance, regulatory tools, and prepare for new development and manufacturing processes. [Ref:35]

Overall, the use of metaverse in healthcare is an exciting area with great potential to transform the way healthcare is delivered and experienced. As technology continues to evolve, it will be interesting to see how metaverse is integrated into healthcare and what new possibilities emerge.

OPEN SOURCE AND OTHER PROGRAMMING LANGUAGE AND METAVERSE

Programming languages play a significant role in the development of the metaverse, a virtual world created by the convergence of physical and virtual reality. Here are some ways programming languages can be used in the development of the metaverse:

Platform development: Open-source programming languages like Python and C++ and other programming language including Java can be used to develop the metaverse platform itself. This can include designing and implementing the communication protocols, creating the user interface, and integrating various components of the platform.

Application development: Open-source programming languages like Python and JavaScript and other programming language including C# can be used to develop applications that run within the metaverse. These applications can include games, social networking applications, virtual marketplaces, and more.

Graphics and animation: Programming languages like C++ and OpenGL can be used to develop high-performance graphics engines for rendering 3D graphics and animations within the metaverse.

Artificial intelligence: Open-source programming languages like Python and R can be used for developing artificial intelligence algorithms and models that can be integrated into metaverse applications. These algorithms can be used for a variety of purposes, including natural language processing, speech recognition, and computer vision.

Data management: Open-source tools like Apache Hadoop and Apache Spark can be used to manage the vast amounts of data generated by metaverse applications. These tools can be used to store, process, and analyze data from various sources, including user behavior data, transaction data, and more. Programming languages like SQL and NoSQL can be used to manage the vast amounts of data generated by metaverse applications. These languages are commonly used in the development of databases and data processing pipelines.

Collaboration: Open-source platforms like GitHub and GitLab can be used to facilitate collaboration between developers working on different aspects of the metaverse. These platforms can be used to share code, track issues, and manage project timelines.

Security: Open-source security tools like OpenSSL and Let's Encrypt can be used to secure the metaverse platform and applications. These tools can be used to encrypt communications, authenticate users, and protect against cyber-attacks.

Overall, programming languages are an essential tool in the development of the metaverse, providing developers with the flexibility and customization needed to create immersive virtual environments. The choice of programming language will depend on the specific needs of the metaverse application and the expertise of the development team. Additionally, the use of open-source software can promote collaboration and knowledge sharing within the metaverse development community.

CHALLENGES

Any change also comes with new set of challenges and similarly to adopt this new technology has certain challenges of its own. With Pharma being a highly regulated industry with GMP regulations to ensure that products are consistently produced and controlled according to quality standards, hence implementing complex processes to training people in new environment might be challenging for digital enterprise solution provider.

But every challenge can be overcome when the benefits offered are immense. But the change is bound to happen, and industries and workforce need to adapt to the same sooner or later.

The privacy of patient data, the high cost of high-tech devices and hardware, and the rising costs of more advanced digital healthcare infrastructure are challenges for the Metaverse in the healthcare market.

CHALLENGES IN IMPLEMENTING DIGITAL TWIN

Privacy and ethical issues: Security, bias, and data ownership issues, especially for digital twins applied in health care, can reduce public trust in the technology.

Technical and infrastructure barriers: Digital twins are difficult to scale up for more complex systems, and the current U.S. network infrastructure may not be adequate for expanded use.

Economic costs: Digital twins can be costly to develop, leading to potential inequities in their use.

Standards and regulations: Existing standards and regulations for digital twin implementation may not be adequate to address their application in complex systems, especially biological ones.

Limited adoption: Digital twin technology is not widely adopted in the clinical routine. Healthcare units (e.g., hospitals and labs) should increase the impact of technology on digital simulations, vital clinical processes, and overall improvement of medical care. Also, the digital twins many remain expensive and not accessible for everyone.

Data quality: Artificial intelligence system in digital twins learn from the available biomedical data but as the data is gathered through several sources/companies, the data quality might not be that good affecting the analysis and representation of such data.

Data privacy: The applications of digital twins require gathering more and more individual level data by healthcare organizations and insurance companies. Over time, these health organizations grasp a detailed portrait of a biological, genetic, physical, and lifestyle related information of a person. Such personalized data might be in use benefitting the company's interest instead of the individuals.

CHALLENGES IN IMPLEMENTING BLOCKCHAIN IN HEALTHCARE

Blockchain is totally new technology, and it has not been fully effective yet. As Blockchain is a new technology, there are many challenges of blockchain in the Healthcare sector:

Lack of technical knowledge: It is not expected that all users will have expensive hardware and software resources. Many users also are not acquainted with the latest technologies. GPUs are required for cryptocurrency mining which is not present in all laptops. This is a big challenge of blockchain.

Lack of paperless method adoption: Many users and doctors prefer paper records. Patients also keep the paper works for their handy purpose. So, adapting to a total paperless blockchain network is a challenging task.

Lack of government involvement: Many hospitals are government owned. So, there is the involvement of the Government to implement rules. Some governments are adamant to adopt the latest technologies. Therefore, blockchain cannot be implemented in government owned hospitals because it is a highly decentralized, distributed ledger.

Lack of privacy: The information is stored in the database of blockchain, and each user has a copy of the database so that if one part of the network fails, the data remains safe so that it can be updated later. Many users prefer to keep their medical problems private. Thus, it hampers an individual's privacy.

Lack of cyber security: Although blockchain is highly secured and there is no involvement of third parties still many attacks like sybil attack, etc. have become a major problem.

Lack of central healthcare: Most healthcare systems are distributed. Many hospitals are in multiple places. So, maintaining a blockchain is a very hectic task. Without a streamlined system, it would be impossible to maintain all the medical records together to adopt blockchain as a technology.

Lack of speed: Speed is very less in Blockchain. The processing speed takes a long, especially if the network is very large. The confirmations take too long and as a result information sharing becomes slow.

CONCLUSION

One of the great opportunities that the metaverse is providing to the pharma industry is to overall "get closer" to the patient – which is something with what the industry has been traditionally struggling with.

The shift of clinical-trial activities closer to patients has been enabled by a plethora of evolving technologies and services: tools such as electronic consent, telehealth care, remote patient monitoring, and electronic clinical-outcome assessments (eCOAs), and of course now the metaverse as well allow investigators to maintain links to trial participants without in-person visits.

The telemedicine will also be revolutionized by the metaverse – totally changing doctors/patients' interactions, we can forecast a paradigm shift in Drug trials thanks to immersive and decentralized technologies such as the metaverse.

In the healthcare industry, the metaverse is rapidly gaining traction. Artificial intelligence, augmented reality, the Internet of Things (IoT), virtual reality, quantum computing, and robotics are all expected to change healthcare delivery and enhance patient outcomes.

The metaverse's role in transforming healthcare cannot be overstated because it combines AI, virtual reality, augmented reality, the internet of medical devices, web 3.0, intelligent cloud, edge and quantum computing, and robotics.

As telehealth amid the COVID-19 pandemic is shifting the patient-healthcare provider relationship from in-person to remote, the metaverse in tandem with AR/VR development solutions is revolutionizing how healthcare is delivered. With its ability to blur the lines between the digital and physical worlds, the metaverse will help curate more immersive, engaged, and lifelike experiences across the healthcare value chain for all stakeholders involved.

The concept of metaverse is still in the early stages of its infancy but there are some predictions as to the impact of metaverse on healthcare. In the not-too-distant future, we expect that comprehensive healthcare in the metaverse will be not only feasible but will also become the norm.

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CONTACT INFORMATION

Your comments and questions are valued and encouraged. Contact the author at:

Aman Bahl
Associate Director, Statistical Programming, Clinical Division, Syneos Health®
Phone: +1-905-399-6715
E-mail: Aman.Bahl@syneoshealth.com
Web: http://www.syneoshealth.com