

EDITORIAL

## Blockchain Technology Predictions 2024: Transformations in Healthcare, Patient Identity, and Public Health

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Keywords: AI-assisted learning; artificial intelligence; ChatGPT; blockchain; digital twin; healthcare; multi-omics; multiversity; public health; Web3.

### *Abstract*

In an era characterized by the convergence of cutting-edge technologies, the world of healthcare and public health is on the brink of a profound transformation that will shape the future of medicine and wellness. This transformation is not merely an incremental step forward but a paradigm shift driven by the synergistic integration of digital twins, blockchain technology, artificial intelligence, and multi-omics platforms collectively propelling us into uncharted territory. Integrating these innovations holds the potential to rewrite the rules of engagement in clinical trials, revamp the strategies for preventing public health crises, and redefine how we manage, share, and secure healthcare data. As we embark on this journey of exploration and innovation, we find ourselves at a pivotal juncture, akin to the invention of the microscope in biology or the discovery of antibiotics in medicine. We are at the crossroads of a new era with immense promise and transformative power.

Received: October 23, 2023; Accepted: October 24, 2023; Published: November 24, 2023

The concept of creating a digital twin (DT) is rapidly evolving from a visionary idea into a reality that promises to redefine our approach to healthcare and personal well-being. In this emerging landscape, we will have the privilege of possessing a virtual alter ego—an entity we can use for experimentation and exploration before making critical decisions about our health and lifestyle. However, as this transformation gains momentum, a central challenge emerges—ensuring the quality and authenticity of the data that fuel these DT models. The integrity of the data that fuel the artificial intelligence (AI) algorithms responsible for constructing DTs is paramount. To achieve this, the integration of blockchain technology becomes indispensable at every stage where patient data are collected, processed, and utilized, particularly in the context of clinical trials. With its capacity to establish proof of data provenance and facilitate robust data auditing, blockchain is poised to become an essential component of this evolving ecosystem. In the near future, it is anticipated that proof of data origin and meticulous

data auditing will not merely be optional but standard practices in creating dependable and internally consistent DTs. In this way, blockchain technology will play a pivotal role in assuring the reliability and coherence of these virtual counterparts, ensuring that they serve as trusted allies in our journey toward healthier and more informed decision-making.

### **Gianluca De Novi, PhD**

The infusion of connected devices into patients' lives and clinical trials has ushered in an era of unprecedented data generation. This data deluge, coupled with advancements in big data analytics, cloud computing, machine learning (ML), and AI, has paved the way for the emergence of DT in healthcare. DTs, virtual representations of real-world entities or processes, offer a novel approach to clinical trials. By leveraging historical and real-time data, DTs can simulate patient trajectories, aiding in more efficient and effective trial design and personalized medicine. However, creating DTs requires vast amounts of patient data,

raising concerns about data security, privacy, and integrity. This is where blockchain technology steps in.

Blockchain, with its decentralized and secure ledger system, ensures data integrity and confidentiality, making it an ideal companion for DTs in healthcare. Blockchain provides a reliable audit trail and access management, addressing critical concerns related to sensitive medical data. If you want to ensure that your DT is reliable, the data ingested to the ML must be genuine. Looking beyond clinical trials, the convergence of blockchain, DTs, and multi-omics platforms promises to redefine public health prevention.

Blockchain enhances data security and interoperability, while DTs offer the ability to simulate health trajectories, enabling proactive interventions. When integrated with multi-omics data, a comprehensive understanding of individual health is achieved, paving the way for tailored preventive strategies. Nevertheless, these innovations also raise ethical questions and challenges. The responsible deployment of these technologies is imperative to protect data privacy and individual rights. The battle for self-sovereignty and digital rights is becoming increasingly relevant as we navigate the digital age, where AI and predictive models can influence and mold human behavior.

### **Natalia Sofia, PharmD, MSc**

#### *Digital Twins and Blockchain: Data-Driven Innovation in Clinical Trials*

During the last decades, the infusion of connected devices across patients' daily lives and within clinical trials has grown considerably. Such devices produce large volumes of data, and along with the advances in big data analytics, cloud computing, and new technologies such as ML and AI, they are altering how we store, process, and exchange health data. Looking into the potential application of DT models in healthcare is challenging due to the lack of an adequate and secure data collection process.

#### *Meet Your Twin*

DTs are considered virtual representations of real-world physical entities/processes from a physical space. DTs bring extraordinary data-driven research, optimization, and innovation by leveraging real-time and historical data to represent the past and present and simulate predicted futures. One key requirement for building a DT environment is that the virtual and physical properties must be congruous at any moment for the corresponding purpose. Within the healthcare scope, a virtual patient in a digital space requires a bulk of data, representing the patient from a physical space. In other words, DTs consist of the relevant IT components for status updates and connectivity. Their unique technological capabilities help untangle complex environments via abstraction, streamline business models, implement AI/ML solutions, and increase

analytical power and confidence in the desired outcomes. But how can we create more efficient and effective clinical trial designs and personalized medicines? DTs can be created by referring to patients in the clinical trial sample. They add information for existing subjects and generate a predicted clinical trajectory according to the clinical study timelines. By using large historical datasets of longitudinal patient information to generate virtual patients, DT models estimate how these patients would evolve over the course of the trial if they were to be given a placebo. DTs can be applied to any therapeutic area, and such innovations may contribute to prospectively designing more efficient and effective trials with higher statistical power or to recover power in ongoing trials impacted by low enrollment or high dropout rates.

#### *Empowering Digital Twins with Blockchain*

Within clinical research, there is a great variety of medical data sources, such as electronic health records, open clinical datasets, data from social networks, and other external applications, which, if acquired properly, could provide a rich repository for creating DT models. Nonetheless, there are security and privacy concerns as medical data are very sensitive and can be used in malicious ways, and DT models focus on creating the virtual environment and do not provide any necessary steps about data integrity and confidentiality breaches. As data are the cornerstone of creating a successful DT model, ensuring data integrity, quality, and confidentiality is critical for a reliable DT system. To that direction, blockchain technology, as a distributed ledger, ensures that all containing blocks' data are distributed to all the peer nodes over the network, and members of disparate groups can carry out transactions and validate them in a distributed environment without needing a centralized system. This provides a highly secure, time-stamped, and reliable audit trail and access management.

In this abstract, we aim to explore the different capabilities of DTs as an emerging technology, raise awareness, and stay two steps ahead. We believe that DTs, along with other advanced technologies such as ML, AI, and blockchain, can offer a major opportunity for clinical research and enable operational efficiency for clinical trials and data management.

### **Ingrid Vasiliu-Feltes, MD, EMBA**

For 2024, the convergence of blockchain technology, DT concepts, and multi-omics platforms is set to usher in a new era of healthcare, profoundly impacting precision public health strategies. This amalgamation of technological advancements holds transformative potential across various domains of public health, with prevention being a prominent focal point.

Blockchain technology, recognized for its incorruptible decentralized ledger system, is poised to catalyze data

security and interoperability in preventive public health measures. By establishing cryptographic hashes and distributed consensus mechanisms, blockchain ensures the veracity and privacy of health data. Blockchain can amplify the impact of DT platforms to monitor public health data. In the context of prevention, this synergy will facilitate real-time tracking of physiological parameters and the early detection of anomalies, thereby allowing for real-time, decisive interventions and personalized preventive strategies.

DTs, as virtual replicas of individual organs, disease states, medical devices, novel therapeutics, hospital rooms, or complex health ecosystems, exhibit their prowess in enhancing prevention efforts when coupled with blockchain capabilities. These intricate models, fed with data from wearables, sensors or bio-implants, and other environmental sources, can simulate potential health trajectories in public health surveillance. These data simulations can change the public and global health paradigm when paired with blockchain's data integrity and provenance capabilities. This predictive prowess enables proactive interventions, effectively targeting potential threats before they escalate into a full-blown health crisis.

In parallel, integrating multi-omics platforms, encompassing genomics, proteomics, and metabolomics data, further augments public health prevention strategies. The blockchain application ensures secure storage and traceability of multi-omics data, maintaining data integrity and accessibility. When combined with DTs, multi-omics insights offer a comprehensive understanding of an individual's genetic predispositions and molecular health indicators. This holistic perspective equips public healthcare stakeholders with the insights to tailor preventive interventions based on intricate biological signatures.

The impending convergence of blockchain technology, DTs, and multi-omics platforms in 2024 promises to reshape the landscape of public health prevention. The fusion of these advancements, accentuating blockchain's data security, DT's simulation capabilities, and multi-omics intricate biological insights, presents a paradigm shift in the precision of preventive measures. However, it is important to emphasize that the success of this trifecta relies on responsible deployment. Proactive, robust cyber-ethics programs must be diligently integrated to safeguard data privacy, ensure responsible data usage, and maintain the digital trust for all public health stakeholders. Only through such responsible deployment, can we harness the full potential of this innovative convergence as we transition to a new era of precision public health?

### **Christine Yan Zang, PhD**

By 2040, blockchain can potentially improve healthcare data and services' security, privacy, interoperability, and innovation. However, it also faces many challenges and

limitations, such as data quality, scalability, performance, regulation, governance, and adoption.<sup>1</sup>

Blockchain could enable smart contracts that automate the execution of agreements between parties based on predefined rules and conditions.<sup>2</sup> For example, smart contracts could facilitate the payment and reimbursement of healthcare services, the verification and credentialing of healthcare providers, the management and distribution of medical supplies and drugs, and the enforcement of data sharing and consent policies.<sup>1</sup>

Blockchain could support digital identity systems that provide a secure and verifiable way of identifying individuals and entities in the healthcare sector.<sup>2</sup> For example, digital identity could be used to authenticate patients, providers, insurers, researchers, and other stakeholders and to link their health records, claims, prescriptions, test results, and other data across different platforms and sources.<sup>1</sup> Blockchain could empower patient-centric approaches that give patients more control and ownership over their health data and decisions.<sup>2</sup> For example, patients could use blockchain to store their personal health records in a decentralized manner, to grant or revoke access permissions to their data, to participate in health research or clinical trials, to access personalized health recommendations or treatments, and to benefit from data monetization or incentives.<sup>1</sup>

Blockchain could foster collaboration and innovation among different stakeholders in the healthcare sector by enabling data sharing and exchange securely and transparently.<sup>2</sup> For example, blockchain could facilitate the creation of health data commons or marketplaces that allow researchers, providers, insurers, regulators, and others to access and use health data for various purposes, such as improving quality of care, advancing medical knowledge, developing new drugs or devices, or creating new business models or services.<sup>1</sup>

### **Frank Ricotta, CEO & Founder, BurstIQ**

In 2024, humans and AI will converge. In 2023, AI stepped out from the shadows with a roar and created one of the most disruptive societal forces we have witnessed in a long time. ChatGPT (Generative Pre-trained Transformer) reached 100 million users in just two months. It took Facebook and YouTube over four years, Twitter over five years, Instagram over two years, and TikTok nine months to reach this milestone.<sup>1</sup> With three social platforms boasting an active user base of over 1 billion, it is safe to say our world is truly connected. It makes sense that ChatGPT had such wide adoption so quickly. With this level of connection, the curiosity and appetite for AI are increasing, which means innovation cycles will continue to accelerate.

These are exciting times, and it is fun to have a front-row seat to watch and participate in the explosion of AI.

Here are my four predictions and two cautions heading into 2024.

#### *Prediction 1: The Rise of Digital Twins*

In 2024, we will witness the emergence of commercially viable DTs for people. What is a DT? Dr. Sofia discussed this earlier. I will add that until now, DT technology has focused on creating a virtual representation of a physical object or system used, for example, for virtual simulations before real devices are designed and deployed. As the industry begins to push the boundaries of this technology coupled with the advancements in AI, particularly generative AI, we are reaching an inflection point where we can now start to represent a person in a variety of ways, including their medical history and records, professional accomplishments, lifestyle, personal IOT (Internet of Things) devices, and relationships. These representations move beyond data about a person; instead, the data generate digital personas that highly reflect the person and, by extension, what a person desires to become. The data you generate are more than just data—it is your digital DNA. Like all DNA, it is the foundation for life. Ultimately, we will hit a point where your DT can act on your behalf, but that won't happen until well beyond 2024.

#### *AI Companions and the Workforce of Tomorrow*

In 2024, we will experience the wide-scale adoption of AI buddies based on generative AI engines, marking a major inflection point for the nature of work and learning. A recent report by McKinsey and Company<sup>3</sup> stated between now and 2030, up to 12 million or more occupational transitions may be needed, and up to 30% of all hours currently worked could be automated (accelerated by generative AI) across the U.S. economy. As a result, companies will revamp their workforce development programs and focus on attitude and aptitude augmented with the ability to teach and verify required skills.

#### *University versus Multiversity*

College enrollment has been declining since 2010, and this trend has accelerated since the start of the pandemic, resulting in a decline of 9% between the spring of 2019 and the spring of 2023.<sup>4</sup> Ten years from now, we will remember 2024 as the time when the educational institutions that managed to thrive adopted the idea of multiversity, prioritized skill-based lifelong learning, and AI-assisted learning (i.e., AI teaching assistants, mentors, and AI-generated learning content) over degree-based education.

#### *Self-Sovereign Identity Adoption*

Blockchain and, by extension, Web3 (a new iteration of the World Wide Web) will finally find a breakthrough application outside of cryptocurrencies—creating, managing, and protecting a true self-sovereign identity. The

World Bank estimates that over 1.1 billion people do not have a legal identity, 2 billion people do not have access to a bank account or financial services, and nearly 1 billion do not have access to adequate healthcare.<sup>5</sup> Trusted and verifiable identity is foundational to creating a world that supports broader access to critical services and human flourishing, including healthcare, property ownership, free and fair elections, and financial access. More importantly, a self-sovereign identity is essential for establishing a trusted digital personal and DT. In the short term, this will allow people lacking a valid ID to gain one and greatly reduce identity theft.

#### *Caution: Navigating the Digital Age and Protecting Your Digital Self*

While AI has tremendous potential for good, there is a reason that most sci-fi descriptions of the future are dystopian. We live in a world where our every move is tracked and recorded, whether we want it or not. Big tech uses our data to support their business interests—usually to influence and monetize our behavior. Our behavior in these digital worlds is already used to create predictive models. AI, in particular generative AI, will evolve these models into psychological profiles that will be used to mold how we think and act. Privacy laws have no chance of keeping up with the rate of advancements.

#### *Caution: Social Credit Scoring*

Over 130 countries, which account for 98% of the global GDP, are exploring central bank digital currencies (CBDCs). Nineteen of the G20 countries are now in the advanced stage of CBDC development. Eleven countries have launched CBDCs, and 21 are in pilot phases.<sup>4</sup>

As a blockchain and Web3 enthusiast, I am a fan of the underlying technology. The caution comes when implemented in a centralized versus decentralized manner. When you combine a CBDC with a centralized implementation of a digital identity and this next generation of surveillance, we will have created a means of control that should not be trusted to any single corporation or government.

We will see radical expansion of those pushing for social credit scores, starting with solutions that may seem beneficial for society. It will be the year that the battle for self-sovereignty will come to the forefront of society. This will no longer simply be an academic discussion. Instead, 2024 will bring the battle for individual digital rights and privacy to center stage.

#### **In Summary**

The year ahead will reveal how dedicated societies and governments are to strengthening individual privacy. Legislation will undoubtedly come into play, but privacy-enhanced technology will evolve from a competitive differentiator to an operational necessity. Decentralized networks,

individual data ownership, transparency, and cracking the AI black box without compromising privacy will build organizational trust. Done effectively, the world will revere AI and its potential to innovate for the greater good.

### Conclusion

As we stand on the cusp of 2024, the fusion of blockchain, DTs, AI, and multi-omics platforms holds the promise of reshaping healthcare and public health. These technologies offer unprecedented opportunities to enhance clinical trials, enable precision public health strategies, and empower individuals with control over their health data. However, these advancements are responsible for safeguarding privacy and ensuring ethical deployment. In the years ahead, we must navigate the complexities of this new era with caution and foresight. Legislation and privacy-enhancing technologies will play crucial roles in balancing innovation with individual rights. Decentralized networks, data ownership, transparency, and responsible AI usage are key pillars in building trust and harnessing the potential of these innovations for the greater good. The year ahead will undoubtedly be a pivotal moment in the battle for digital rights and privacy as we strive to realize the full potential of these transformative technologies while upholding our ethical responsibilities.

### Funding Statement

No funding was provided for the preparation of this article.

### Financial and Non-financial Relationships and Activities

Ingrid Vasiliu-Feltes reports no conflict of interest to report. Each contributor is affiliated with the organization listed in the article. Dr. De Novi and Dr. Vasiliu-Feltes are members of the BHTY Editorial Board.

### Author Contributors

Each author contributed their section of the article.

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