

BLOCKCHAIN™ IN HEALTHCARE — T O D A Y —

Top 10 Blockchain Predictions for the (Near) Future of Healthcare

John D. Halamka,¹ Gil Alterovitz,² William J. Buchanan,³ Tory Cenaj,⁴ Kevin A. Clauson,⁵ Vikram Dhillon,⁶ Florence D. Hudson,⁷ Manouchehr (Mitch) Mokhtari,⁸ Dennis A. Porto,⁹ Ana Santos Rutschman,¹⁰ Anh L. Ngo¹¹

Affiliations: : ¹Chief Information Officer, Beth Israel Deaconess System, Chairman, New England Healthcare Exchange Network (NEHEN), International Healthcare Innovation Professor, Harvard Medical School, and practicing emergency physician; ²Faculty, Harvard Medical School/Boston Children's Hospital, Massachusetts Institute of Technology; ³Professor, School of Computing, Edinburgh Napier University; Fellow, BCS and IET; ⁴Founder of Partners in Digital Health, and Publisher of the open access peer review journals *Blockchain in Healthcare Today*, and *Telehealth and Medicine Today*; ⁵Associate Professor, Lipscomb University College of Pharmacy & Health Sciences; ⁶Research Fellow, Institute of Simulation and Training at University of Central Florida; ⁷Special Advisor, TrustedCI, The NSF Cybersecurity Center of Excellence at Indiana University; Special Advisor for Next Generation Internet, Northeast Big Data Innovation Hub at Columbia University, Co-founder Blockchain in Healthcare Global at IEEE-ISTO; ⁸Associate Professor, School of Public Health, University of Maryland, College Park; ⁹Lewis Wendell Hackett award recipient at Harvard and contributor to the blockchain and bitcoin curriculum at Harvard Business School; ¹⁰Assistant Professor of Law, Center for Health Law Studies, Saint Louis University School of Law; ¹¹Faculty, Harvard Medical School, Beth Israel Deaconess Medical Center, Department of Anesthesia, Critical Care, and Pain Medicine;

Key words: Blockchain, Consent, Genome, Healthcare, Prediction, Medical Records, Providers, Infrastructure, Monetization, Remittance, Startups, Supply Chain

Corresponding author: Tory Cenaj, teecellc@gmail.com

Section: Opinions, Perspectives, and Commentary on a Current Trend or Issue Impacting the Sector

To review blockchain lessons learned in 2018 and near-future predictions for blockchain in healthcare, Blockchain in Healthcare Today (BHTY) asked the world's blockchain in healthcare experts to share their insights. Here, our internationally-renowned BHTY peer-

review board discusses their major predictions. Based on their responses, presented in detail below, ten major themes (Table) for the future of blockchain in healthcare will emerge over the 12 months.

Blockchain will become an essential part of consent management in healthcare

First, consent is now stored in individual provider electronic health records, hospital medical record departments, and in stacks of paper on fax machines. Consent is gathered for every procedure or at every visit. Consent is local to each provider, not at a patient level for all sites of care across a patient lifetime. Many startups are working on a radical revision of the consent process—storing patient consent for data exchange/privacy preferences and treatments on the blockchain, such that all stakeholders can access consents from one place and respect patient wishes. This approach will

reduce administrative burden and enhance the patient care experience.

Micropayments will increasingly migrate to blockchain

Third, in a world of value-based purchasing, healthcare providers are reimbursed for wellness, not the quantity of care they deliver. Many startups are working on wellness applications that provide incentives to ‘do the right thing.’ An easy-to-use universal payment interface for providing micropayments to patients when they achieve goals/outcomes would accelerate innovation. Similarly, tracking co-pays and the litany of employee share of medical expenses could be simplified with a blockchain-based universal payment interface

Table . Ten major themes for the near-term future of blockchain in healthcare

Predictions
#1. Blockchain will become an essential part of consent management in healthcare
#2. Remittance and micropayments will increasingly migrate to blockchain
#3. Non-cash assets including outcomes will be tokenized
#4. Providers will be credentialed on chain
#5. Improvements to blockchain infrastructure will reduce electricity requirements and enhance speed/scalability
#6. Supply chain integrity will be tracked on blockchain
#7. Education of stakeholders will refine use cases for blockchain and accelerate adoption
#8. Opportunities for monetization of data, including the genome, will be enhanced by blockchain
#9. Integrity of medical records will be an essential use case for blockchain
#10. Existing blockchain in healthcare startups will be acquired and we will see substantial consolidation of blockchain in healthcare offerings

Non-cash assets including healthcare outcomes will be tokenized

Second, although blockchain has roots in cryptocurrency, a token can really represent anything—real estate, a physical object, or even an outcome. Tokens facilitate managing for results or outcomes in healthcare. A new startup, Proof of Impact, has started to measure patient-outcomes and offer non-governmental

organizations the opportunity to ‘buy’ outcomes. For example, there could be a marketplace for patients successfully treated for a disease. Instead of just providing grants, foundations could pay for outcomes documented in the blockchain.

Providers will be credentialed on chain

Fourth, with over 1000 insurance companies in

the country, filling out paperwork to document provider training and licensure is a nightmare. The Synaptic Health Alliance aims to simplify this process by putting all credentialing information on a distributed public ledger for all stakeholders to access.¹

Improvements to blockchain infrastructure will reduce electricity requirements and enhance speed/scalability

Fifth, proof-of-Work approaches consume the yearly electrical output of Ireland. Building trust through other means will preserve trust but radically reduce the computing footprint. Similarly, transactional speeds will increase and blockchain as a service will enhance ease of use (by hiding the complexity of blockchain behind a set of cloud-hosted functions, with simple to use application programming interfaces).

Supply chain integrity will be tracked on chain

Sixth, recently I was traveling in India with a few clinicians who purchased medications at a local pharmacy to treat respiratory ailments. There was no way to track the validity of the lot numbers nor the purity of the compounds. A blockchain approach to pharmaceutical supply chain would ensure the integrity of the products.

Education of stakeholders will refine the use cases for blockchain and accelerate adoption

Seventh, every day I do an interview with some publication to explain what blockchain doesn't do (i.e., it's not a high-performance database, an analytical tool, or the solution to managing person identity). We have no idea who actually posts transactions to the blockchain. There are many reasons to use the blockchain as described above—consent, credentialing, data integrity guarantees, supply chain management, and micropayments. As more stakeholders are educated about the pros and cons of blockchain, high value use cases will be implemented more

widely.

Opportunities for monetization of data including the genome will be enhanced by blockchain

Eight, many startups recognize that data are the new 'oil.' Or, for those who remember watching *The Graduate*, in 1967, Dustin Hoffman would have been told to monetize data instead of plastics. However, resale of data without full disclosure and consent has proven problematic—just look at Facebook's challenges.² What if a marketplace for data enabled people who want to contribute data—for some public good such as clinical trials/clinical research/population health—to be paid each time their data were used? Patients could participate in this marketplace with eyes wide open and be a part of sharing any gains made from their anonymized contributed data. Nebula Genomics, for example, is exploring this idea to accumulate genomic data for the development of precision medicine tools more rapidly.³

Integrity of medical records will be an essential use case for blockchain

Ninth, malpractice assertions happen. Health outcomes are not always good and inevitably someone is blamed. When plaintiff attorneys request historical medical records, they often claim the records are faked/alterd to remove any evidence of medical mistakes. We provide audit trails to validate that records have not been changed. The attorneys then claim the audit trails were altered (which is impossible). If a distributed ledger technology with unassailable trust were used to guarantee the integrity of the medical record, the burden on providers, IT departments, and attorneys would be reduced. The records themselves would not be stored on chain, just a hash (a one-way mathematical transformation that is unique for every document). If a record is produced today and its hash matches the hash stored on the blockchain

when the record was created, all stakeholders can be assured the record was never changed.

Existing blockchain in healthcare startups will be acquired and we'll see substantial consolidation of blockchain in healthcare offerings

Finally, in my work as a blockchain expert, I advise many startups and hear 50 pitches for everyone I chose to advise. The marketplace of companies offering blockchain is large and filled with more PowerPoint presentations than products. Many of these startups will fade away for lack of business model. Otherwise, the promising startups will be acquired and consolidated, such as Change Healthcare did with Pokitdok (and it's Dokchain),

Those are our forecasts. Below are the original comments from experts that led to this top 10 list:

Gil Alterovitz: Practical implementations of blockchain in healthcare will come, but they will not be specific to healthcare. For example, developments in blockchain for supply chain are emerging where healthcare is one of many sectors that will be affected.

Second, blockchain-based currency has started to be used for remittances. Such applications could begin to affect healthcare funding patterns in developing countries.

William H. Buchanan: This year will be the year of commitment, tokenization, identity, anonymity, regulation, and the start of public key encryption finally replacing 'wet' signatures in our healthcare systems. We are now at the point with blockchain that we understand what should (and should not) be added to the ledger, and with regulations such as General Data Protection Regulation (GDPR)⁴, we must ensure respect for citizens' rights of privacy and

consent. Our new health care world must be built on a solid digital foundation of cryptography and trust.

Increasingly, we must anonymize onto the ledger, but for us still to create a consensus for the current state of an infrastructure. Our blockchain world will thus become increasingly anonymized, in order to ensure privacy protection at its lowest layers, and with each transaction blinded in some way.

Some cryptocurrencies - such as Monero and ZCash, provide enhanced privacy - and are guiding lights in hiding transaction details, while still being able to integrate high levels of trust. The owner of the data will be able to hold these blinding factors and reveal them as required. In this way, citizens will show commitments to things and then reveal the details of their commitment to those whom they trust. This will help anonymize our ledgers, while building infrastructures for regulation.

In addition, we are entering a year will be the year that our world becomes truly tokenized, and where we move our focus from cryptocurrencies to crypto assets. Unfortunately, our legal infrastructures do not quite match to a distributed ledger world; so, we will see some nations of the world move towards developing a legal definition of this world. Liechtenstein is a guiding light in this with its Blockchain Act. Other nations are sure to follow, especially to support innovation, while building up trust in transforming our public sector. A strong trust infrastructure and regulatory framework must be core part of the implement of blockchain methods within healthcare. If, in the near-term, we started to use cryptography properly within our healthcare systems, we will have at least started to build our healthcare systems on a trusted foundation.

Tory Cenaj: We will see a groundswell of education. Clinicians and health consumers will begin to understand the technology—what it does and how it applies to the health sector. We will begin discourse not with the history of..., but with “*blockchain technology is...*” and “*blockchain technology does...*”

There will be an increase in drug discovery business models that use intersecting technologies to lower the cost of developing drugs, such as combining blockchain tech and telehealth and medicine for clinical trials.

We will see more bitcoin ATMs, retailers accepting bitcoin, and mobile tech use of payments (with digital wallets) and scanning codes at counters. This will spur curiosity, education, and help expand initiatives in healthcare.

There will be ‘lift-off’ for a token economy that offers direct buying and selling power to healthcare consumers. For example, if a woman ‘donates’ her ovum for \$10K (through an intermediary),⁵ how much will personal health data and genome be bought and sold for (without the intermediary)?

There will be “lift off” for a regulated global token exchange that is linked on a parallel track with all exchanges around the globe. Governments and governing bodies will convene to respond to this urgency, and present one unified solution.

I wonder about our beloved elders. It will be challenging to train them on tech at this stage. Devices and sensors will expand a new home healthtech work force. Blockchain tech security and immutability will enhance solutions for new “smart city infrastructure,” including lowering costs for ecosystems and environments built for the elderly.

Kevin Clauson: From the beginning, healthcare has actively tried to dissociate blockchain and bitcoin. “Blockchain, not Bitcoin” was the oft-repeated mantra at healthcare conferences, press releases, and on conference calls.

While the desire to do so is understandable because of the murky history of bitcoin and cryptocurrencies in the public consciousness and the disruption-resistant, risk-averse nature of the healthcare industry, it is still a mistake to do so. It is a mistake if the intent is to understand and evaluate blockchain in the broader healthcare industry. The cryptocurrency market is still a substantial driver for companies building at the intersection of blockchain and healthcare—particularly for startups.

After a meteoric rise in the cryptocurrency market and of cryptocurrency valuations in 2017, 2018 was characterized by plummeting prices of a ‘crypto winter.’ *Prediction: we are entering a time of consolidation and acquisition in healthcare-focused blockchain companies*, as foreshadowed by Change Healthcare acquiring PokitDok. This trend in will lead to healthcare companies demonstrating better resourced efforts in leveraging blockchain and distributed ledger technology (DLT) as well as superior organization, integration, and (hopefully) impact.

Vikram Dhillon: Fitness wearables are producing an enormous amount of data that can be captured in actionable formats.⁶ Connected devices can easily provide data points such as blood pressure, weight, pulse, and sleep patterns. Scheduling timely exports of such data allows better understanding of how patients implement lifestyle changes for chronic diseases such as diabetes. Committing snapshots of these data to the blockchain can incentivize and reward lifestyle changes.

With the microtransaction payment structure built into the blockchain, rewards programs can be turned into smart contracts that dispatch reward tokens to wallets on blockchain. As more healthcare providers and partners join such a network, the tokens will have more value and be redeemable for discounts such as co-pay for clinic visits.

Florence Hudson: Blockchain technology is definitely on the ‘hype cycle.’ Now is the time for technology and healthcare leaders around the world to work together to bring blockchain into the reality cycle.

Blockchain will be deployed across the healthcare industry to improve secure healthcare data sharing toward the goal of precision medicine, accelerating research, and improving healthcare outcomes. This will include use cases in personal health records, wearables, lab sample data management, supply chains, and research.

As I presented at the 2018 Society of Women Engineers Conference in Minneapolis, "Blockchain: From Hype to Real Value," to a standing room only audience, the data sharing imperative to improve healthcare outcomes will be well served by blockchain and other technologies working together to deliver Trust, Identity, Privacy, Protection, Safety, and Security (TIPSS) for humans, devices and data.

In September 2018, the Institute of Electrical and Electronic Engineers (IEEE) published that it is sponsoring initiatives with technology and healthcare leaders around the world, including device manufacturers, pharmaceutical companies, providers, and regulators, to enable standards for clinical Internet of Things device and data interoperability with blockchain, as well as lab sample data tracking and management with blockchain. We are working

together to define new standards, create real demonstration pilots, and deliver the value blockchain has to offer.

Manouchehr (Mitch) Mokhtari: We will witness an explosion of ‘permission-ed’ or ‘club blockchain’ in the healthcare and other sectors. This will be analogous to the proliferation of the intranets or personal computers, as opposed to the mainframe or blockchain as a computer for the world. The club blockchain will exclude non-members and ensure non-rivalrous benefits to the members.

Anh L. Ngo: My initial response could have been, "Total World Domination," but that would be an overstatement and only used to catch the

reader's attention. More to the point, blockchain will likely be intertwined with other aspects of technological advances such as artificial intelligence (AI), Internet-of-Things, and mobile applications for ease of adoption and use.

I believe the blockchain will permeate several aspects of healthcare, with first adoptions occurring in areas involving financial transactions. Those include micropayments (deductibles, prescriptions, traditional cash pay), insurance processing and claims, and payments and quality assurance involving medical supply chain management. These are areas where high friction, massive inefficiencies, and costs can be reduced with a new way of managing trust in a transaction.

Other areas of healthcare that can involve adoption of blockchain include physician credentialing, patient consent management, and, of course, medical records. Of note, medical records have a long way to go since medical data are very resource-intensive and will require creative measures to limit the impact of large

data on stakeholders on the blockchain platforms.

Dennis A. Porto: In the coming year, the distinction between enterprise blockchains and public blockchains will begin to blur. These large public blockchains, especially bitcoin, have best captured what makes blockchains valuable: trust minimization and tamper resistance approaching the notional ideals of trustlessness and immutability.

Enterprise blockchains will exist perhaps as sidechains to or layers above bitcoin, where they can periodically settle on the main bitcoin blockchain without being encumbered by scaling issues characteristic of a public cryptocurrency.

We will see serious efforts to create and capture value in healthcare blockchain: pharmaceutical supply chain management, opioid and cannabis diversion control, physician credentialing, as well as clinical trial and patient data management.

We will also see a number of projects fail despite their good intentions. Successful projects will be those that have a narrow use of blockchain to solve a problem that is impossible with a traditional database.

Finally, innovation will continue to occur at the protocol level. I anticipate that proof of work will continue to dominate, and that the most impactful technical innovations will focus on optimizing this particular consensus mechanism.

Ana Santos Rutschman: We will see more companies piloting blockchain projects involving collection of genomic data, and we will see more opportunities for monetization of genomic data. At the same time, we will see growing awareness of privacy issues in this

field. We will also see more public funding directed at blockchain-based genomic data projects.

Final Thoughts

William H. Buchanan: Let this next year be a time for building a solid foundation for future of healthcare and put digital trust and the rights of the citizen at its core.

Wishing you success!

Contributors: Each author contributed their experience and insight into the future predictions for blockchain.

Conflicts of Interests: None

References

1. Synaptic Health Alliance. Joining forces to improve healthcare. 2019. Baus A. Available at URL: <https://www.synaptichealthalliance.com/about-us>
2. Gaus A. 4 key challenges facing Facebook in 2019. TheStreet. 2018. Available at URL: <https://www.thestreet.com/technology/4-key-challenges-facing-facebook-in-2019-14815098>
3. Nebula Genomics. The future of your health is in your DNA. 2018. Available at URL: <https://www.nebula.org>
4. General Data Protection Regulation. intersofrt consulting. 2018. Available at: <https://gdpr-info.eu>
5. Help a loving family-be an egg donor! Up to \$10k + travel expenses! (Portland, OR). Craigslist, Corvallis, Oregon. Available at URL: <https://corvallis.craigslist.org/etc/d/portland-help-loving-family-be-an-egg/6788923222.html>

6. Hudson F, Clark C. Wearables and Medical Interoperability: The Evolving Frontier. *Computer*. 2018: 86-90. Available at URL: <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8481273>
7. Artificial Intelligence (AI). Techopedia. 2019. Available at URL: <https://www.techopedia.com/definition/190/artificial-intelligence-ai>
8. Bitcoin. Wikipedia. 2019. Available at URL: <https://en.wikipedia.org/wiki/Bitcoin>
9. Blockchain. Oxford Living Dictionaries. 2019. Available at URL: <https://en.oxforddictionaries.com/definition/blockchain>
10. Cryptocurrency. Wikipedia. 2019. Available at URL: <https://en.wikipedia.org/wiki/Cryptocurrency>
11. Thake M. What's the difference between blockchain and DLT? Nakamoto. 2018. Available at URL: <https://medium.com/nakamoto-to/whats-the-difference-between-blockchain-and-dlt-e4b9312c75dd>
12. Woods J. Enterprise Blockchain Has Arrived. CriptoOracle. 2018. Available at URL: <https://medium.com/crypto-oracle/enterprise-blockchain-has-arrived-2d2e4d8ec0d>
13. IT Glossary. Internet of Things. 2019. Available at URL: <https://www.gartner.com/it-glossary/internet-of-things/>
14. Monero (cryptocurrency). Wikipedia. 2019. Available at URL: [https://en.wikipedia.org/wiki/Monero_\(cryptocurrency\)](https://en.wikipedia.org/wiki/Monero_(cryptocurrency))
15. Immutable object. Wikipedia. 2018. Available at URL: https://en.wikipedia.org/wiki/Immutable_object
16. Viewpoints. Change Healthcare Acquires PokitDok Assets. Change Healthcare. 2019. Available at URL: <https://www.changehealthcare.com/blog/change-healthcare-acquires-pokitdok-assets/>
17. Proof-of-work system. Wikipedia. 2019. Available at URL: https://en.wikipedia.org/wiki/Proof-of-work_system
18. Massessi D. Public vs private blockchain in a nutshell. Medium. 2018. Available at URL: <https://medium.com/coinmonks/public-vs-private-blockchain-in-a-nutshell-c9fe284fa39f>
19. Zcash. Wikipedia. 2019. Available at URL: <https://en.wikipedia.org/wiki/Zcash>

Glossary of Terms

Artificial intelligence (AI): An area of computer science that emphasizes creation of intelligent machines that work and react like humans. Some of the activities computers with artificial intelligence are designed for include speech recognition. ⁷

-
- Bitcoin:** A cryptocurrency (i.e., a form of electronic cash) is a decentralized digital currency without a central bank or single administrator that is sent from user-to-user on the peer-to-peer bitcoin network without intermediaries.⁸
- Blockchain:** A system in which a record of transactions made in bitcoin or another cryptocurrency are maintained across several computers linked in a peer-to-peer network.⁹
- Club blockchain:** A "permission-ed" blockchain.
- Cryptocurrency (or crypto currency):** A digital asset designed to work as a medium of exchange that uses strong cryptography to secure financial transactions, control the creation of additional units, and verify the transfer of assets.¹⁰
- Crypto winter:** A period where the value of cryptocurrencies decline.
- Distributed Ledger Technology:** An umbrella term used to describe technologies that distribute records or information (e.g., accounting ledgers) among those using it, either privately or publicly.¹¹
- Enterprise blockchain:** The use of blockchain within corporations¹²
- Internet-of-Things:** The interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data.¹³
- Monero:** An open-source cryptocurrency created in April 2014 that focuses on fungibility, privacy and decentralization. Monero uses an obfuscated public ledger, meaning anybody can broadcast or send transactions, but no outside observer can tell the source, amount or destination.¹⁴
- Immutable:** An object whose state cannot be modified after it is created.¹⁵
- PokitDok, Inc.:** A platform-as-a-service company for healthcare, which was acquired by Change Healthcare in 2018.¹⁶
- Proof-of-Work (PoW):** A system (protocol or function) that is an economic measure to deter denial of service attacks and other service abuses such as spam on a network, by requiring some work from the service requester, usually meaning processing time by a computer.¹⁷
- Public Blockchain:** A permissionless blockchain. Anyone can join the blockchain network, meaning that they can read, write, or participate. Public blockchains are decentralized. No one controls the network, and they are secure in that the data cannot be changed once validated on the blockchain.¹⁸
- Private blockchain:** A permissioned blockchain (i.e., places restrictions on who is allowed to participate in the network and in what transactions).¹⁸
- Zcash:** A cryptocurrency aimed at using cryptography to provide enhanced privacy for its users compared to other cryptocurrencies such as Bitcoin. Like Bitcoin, Zcash has a fixed total supply of 21 million units.¹⁹