Blockchain in health care: hype, trust, and digital health

The promise of digital health care continues to be enthusiastically promoted but has been difficult to realise. Evidence-based practice, along with patient safety assurances, information governance, and certification, does not fit easily with schemes to accelerate innovation. Trust in the efficacy and safety of new models of care, such as that potentially delivered by artificial intelligence (AI), remains uncertain. Blockchain technology might contribute to overcoming these problems by enabling greater openness, transparency, and trust.

Blockchain was first conceptualised in 2009 for the first digital crypto-currency, Bitcoin.[1] Blockchain is a decentralised collection of technologies to allow for the storage of data that are permanent and immune to fraud, such as financial transactions, without the need for a central or trusted authority like a bank. The concept has grown beyond the exchange of payments to include smart contracts in which software algorithms manage the exchange of value through the use of tokens. With investment from large multinational technology companies and venture capital, the use of blockchain technology is growing in markets beyond finance such as the pharmaceutical and health-care industries.[2]

In Estonia, every citizen's health record is secured with blockchain technology, which allows them to express consent to different uses of their data and to be assured as to who has viewed their records.[3]

Companies and researchers have also begun development of blockchain use for managing access to health data. Blockchain's ability to create records of transactions that cannot be altered could potentially be applied to any problem where a record of the supply chain is important. For example, the recording of the delivery of a drug package could be created for every step of its journey from the factory to the patient, including details of whether it has been stored at the correct temperature, the price at which it was sold, when it was dispensed, and to whom. This approach has the potential to improve patient safety and protect against counterfeiting and fraud.[4]

Blockchain might also have a role in resolving two challenges associated with the internet: trust and identity.[5] The ability to digitise trustworthy records in a way that is independent of a single (potentially unsafe) database might allow the validation of clinical credentials across different health-care providers, providing new opportunities for supporting adoption of a digital environment for improving health care.[6] Furthermore, use of blockchain in research could have potential for fuller and more public records of research data and activity that might help address the reproducibility challenge by creating links across research communities.

Blockchain technology faces many hurdles to wider adoption, and it is largely unproven at scale in health-care applications. Limitations of the technology include high energy consumption[7] and the slow speed of recording transactions, arising because of the need to be a secure, permanent record that requires computationally intensive digital signing. Additionally, data stored in public chains are not private and, even if the data are encrypted, patient data stored on a public chain could be at risk. For these reasons, private data, especially large files such as multimedia, are often stored outside of blockchain.[8] Finally, data that are stored in the blockchain ledger cannot be deleted, which could conflict with the EU General Data Protection Regulation, whereby patients must be able to opt out of the storage and use of their data.[9] Blockchain is an immature technology that might not be sustainable, and individual platforms can be exposed to security flaws, such as the attack on

Ethereum Classic in January, 2019, with the theft of almost US$500 000,[10] especially with the waxing and waning in popularity of various blockchain platforms and when security is based on no single provider holding a majority of the ability to compute tokens.

Blockchain technology will need to focus on its foundational strengths to create secure, immutable records with increased trust and transparency.[11] This development could be transformative and is described by blockchain enthusiasts as Internet 3.0.[12] Blockchain might transform how decisions and the interactions between clinicians and patients are recorded. In an environment in which apps and AI-based algorithms are being brought into health care without appropriate validation or understanding,[13] blockchain provides opportunities for recording in a transparent manner the interactions of health-care systems with digital technologies, such as recording the detail and provenance of information in a shared health record. Such use of blockchain might provide evidence to support initiatives such as the UK's National Institute for Health and Care Excellence (NICE) and National Health Service (NHS) digital frameworks for evaluation.[14] This transparency might act as a catalyst for the trust and subsequent adoption of some AI-based tools in health care. Additionally, blockchain technology could provide a resource of trusted data and interactions that themselves could be the foundation of a new generation of AI-based systems that are based on secure, trusted data contained within the blockchain. However, this potential is still yet to be shown in the real world, with much more research and maturation of blockchain necessary before blockchain platforms can be used safely and routinely across the wider health system. To do this, more research on the value and benefits of blockchain is needed to take us beyond the technological art of the possible and to guide the development of best practice for blockchain in health care.

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1   Nakamoto S. Bitcoin: a peer-to-peer electronic cash system. Bitcoin, 2008. https://bitcoin.org/en/bitcoin-paper (accessed May 1, 2019).
2   Mettler M. Blockchain technology in healthcare: the revolution starts here. 2016 IEEE 18th International Conference on e-Health Networking, Applications and Services, Healthcom 2016; Munich, Germany; Sept 14–16, 2016. DOI:10.1109/HealthCom.2016.7749510.
3   Heston T. A case study in blockchain healthcare innovation *Int J Curr Res* 2017; **9:** 60587–88.
4   Sylim P, Liu F, Marcelo A, Fontelo P. Blockchain technology for detecting falsified and substandard drugs in distribution: pharmaceutical supply chain intervention. *JMIR Res Protoc* 2018; **7:** e10163.
5   Pentland A, Shrier D, Hardjono T, Wladawsky-Berger I. Towards an Internet of trusted data: input to the Whitehouse Commission on Enhancing National Cybersecurity. In: Hardjono T, Pentland A, Shrier D, eds. Trust::Data—a new framework for identity and data sharing. Oxford: Visionary Future, 2016: 21–49.
6   Gietl D, Brody P, Champion de Crespigny A, Beal A. blockchain in health: how distributed ledgers can improve provider data management and support interoperability. 2016. https://www.hyperledger.org/wp-content/uploads/2016/10/ey-blockchain-in-health.pdf (accessed May 1, 2019).
7   Truby J. Decarbonizing Bitcoin: law and policy choices for reducing the energy consumption of Blockchain technologies and digital currencies. *Energy Res Soc Sci* 2018; **44:** 399–410.
8   Ekblaw A, Azaria A, Halamka JD, Lippman A. A case study for blockchain in healthcare: "MedRec" prototype for electronic health records and medical research data. Cambridge, MA: MIT Media Lab, 2016.
9   European Commission. Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation). *OJ* 2016; **L119:** 1–88.
10 Nesbit M. Deep chain reorganization detected on Ethereum Classic (ETC). The Coinbase Blog, Jan 7, 2016. https://blog.coinbase.com/ethereum-classic-etc-is-currently-being-51-attacked-33be13ce32de (accessed May 16, 2019).
11 Cunningham J, Ainsworth J. Enabling patient control of personal electronic health records through distributed ledger technology. *Stud Health Technol Inform* 2018; **245:** 45–48.
12 Alabdulwahhab FA. Web 3.0: the decentralized web blockchain networks and protocol innovation. 2018 1st International Conference on Computer Applications & Information Security (ICCAIS); Riyadh, Saudi Arabia; Aug 23, 2018. DOI:10.1109/CAIS.2018.8441990.
13 The Lancet. Is digital medicine different? *Lancet* 2018; **392:** 95.
14 Greaves F, Joshi I, Campbell M, Roberts S, Patel N, Powell J. What is an appropriate level of evidence for a digital health intervention? *Lancet* 2019; **392:** 2665–67.