Blockchain, health disparities and global health

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ABSTRACT

Health disparities remain vast around the world and are perpetuated by error-prone information technology systems, administrative inefficiencies and wasteful global health spending. Blockchain technology is a novel, distributed peer-to-peer ledger technology that uses unique, immutable and time-stamped blocks of records or sets of data that are linked as chains through cryptography to more reliably and transparently store and transfer data. Various industries have successfully leveraged blockchain technology to disintermediate and reduce costs, but its use in healthcare and global health has remained limited. In this narrative review, we describe blockchain technology and elaborate on the experiences and opportunities for leveraging blockchain within global health in terms of cryptocurrencies and health financing, supply chain management, health records, identification and verification, telehealth and misinformation. We conclude each section with an analysis of the restrictions imposed by the COVID-19 pandemic to highlight blockchain's unique opportunities for improving healthcare services and access to care during future pandemics or natural disasters.

Summary box

What is already known?

- Health disparities are pervasive throughout the world and are perpetuated by error-prone information technology systems, administrative inefficiencies and wasteful global health spending.
- Blockchain technology, a novel, distributed peer-to-peer ledger technology, is increasingly used in various industries to disintermediate, improve efficiency and transparency and reduce costs; however, its use in healthcare and global health has remained limited.

What are the new findings?

- Opportunities exist to leverage blockchain technology in global health in terms of cryptocurrencies and health financing, supply chain management, health records, identification and verification, telehealth and misinformation.
- Blockchain can now be leveraged to help mitigate the healthcare impact and disparities arising from the COVID-19 pandemic.

INTRODUCTION

Despite vast spending by high-income countries on domestic health systems and cumulative spending on global health, health disparities remain pervasive across the globe. The USA spends nearly US$4 trillion on health annually, yet continues to have some of the poorest health indicators and life expectancy among high-income countries. Global leaders were determined to meet the millennium development goals and now the sustainable development goals to address health disparities; nevertheless, reaching those targets remains a challenge. An often overlooked issue is wasteful spending: in the USA, up to 25% (or US$935 billion) of healthcare spending is wasted each year,[1] whereas approximately US$455 billion of global health spending is lost to fraud.[2] In addition, inefficiencies in health supply chains contribute to waste in operations of up to 50% of the total operating costs.[3] Meanwhile, secure data storage has been complicated by existing, error-prone systems, with over four billion records exposed globally through data breaches in the first half of 2019.[4] These shortfalls will require innovative solutions and paradigm shifts in order to increase efficiency, reduce waste and level access to healthcare.

Blockchain emerged as a novel technology in various industries, including the banking, technology and food and agriculture sectors, and has been touted as the next greatest invention since the internet. It uses a decentralised, distributed ledger to establish peer-to-peer

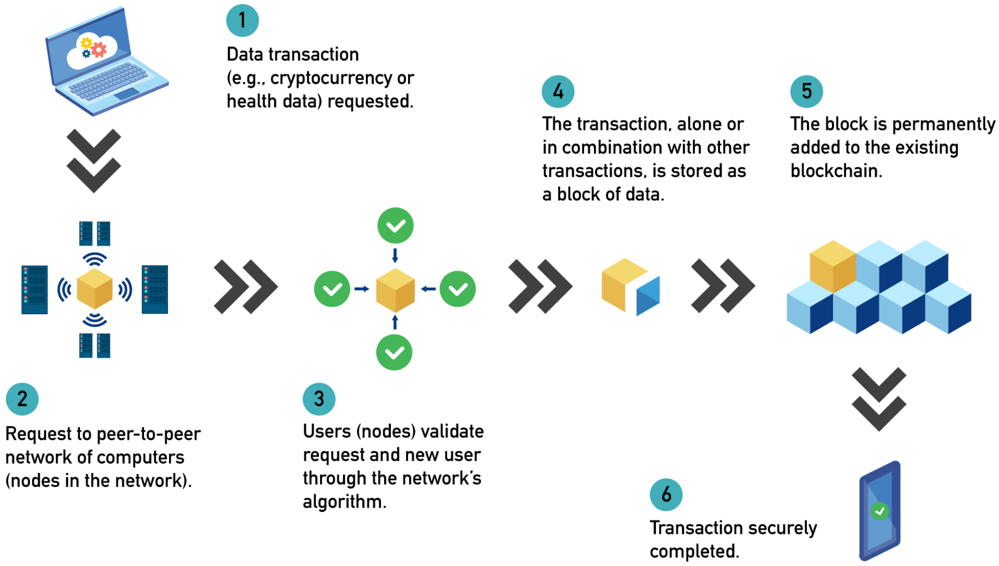

Figure 1 Overview of blockchain.

(P2P) or business-to-business networks with end-to-end encryption (figure 1). Encryption occurs either privately on both ends (symmetric cryptography) or, more commonly, privately on one end and publicly on the other (asymmetric cryptography). Blockchain refers to the chain of digital 'blocks', each representing a record or a set of data, which are connected digitally through cryptography with unique hash codes. Each unique hash represents data in a specific location in the blockchain that is difficult to change. This immutability implies an unchangeable, comprehensive log of transactions that have taken place on the blockchain, which allows for a transparent history and reliable and safe storage. Each block can provide information regarding actions, times, transactions and other data, together creating a 'ledger' or timeline of how the information is structured. Blocks can be added to the ledger if they are valid and approved by a consensus algorithm across a distributed network, often involving thousands of independent 'nodes' or servers. This differentiates it from conventional mechanisms whereby a central authority records such transactions. As a distributed and encrypted technology, blockchain allows for secure and transparent data transactions, whether mere information or cryptocurrency, to take place with sequential timestamping. Additionally, blockchains are typically open-source, thereby publicly presenting the programming code to validate blocks and the transaction data within each block. As a result, blockchain has recently attracted increasing attention from various sectors, including healthcare. The COVID-19 pandemic accelerated that interest with a specific focus on medical supply chains and contact tracing, among other potential opportunities (figure 2).[5] Despite its potential, little investments have been made to leverage blockchain technology in variable resource settings.[6]

Here, we present a narrative review of the growth and potential of blockchain technology in healthcare, highlighting the opportunities to address disparities and global health inequities, especially during the COVID-19 pandemic.

CRYPTOCURRENCIES

Cryptocurrencies, or decentralised P2P digital currencies, are among the most widely known applications of blockchain technology. The data stored in blockchain ledgers refer to all transactions and ownership of the cryptocurrency. The most widely known cryptocurrency is Bitcoin, which emerged in 2009 out of distrust in traditional financing borne from the 2008 economic crisis.[7] Today, over 100 cryptocurrencies are used as investments, similar to stocks, as well as in commercial and private payments.[8] While cryptocurrencies have not replaced reserve currencies such as the US dollar, interest in them is growing as they may provide opportunities for universal access to financing.[9] Marginalised populations face substantial barriers in setting up a bank account, such as geographic and administrative barriers as well as distrust in local financial institutions. Cryptocurrencies can instead allow for increased accessibility, only requiring internet access. However, it must be noted that cryptocurrencies are associated with greater technological complexity compared with conventional fiat currency. While consumers are not required to understand the underlying blockchain technology, electronic cryptocurrency wallets, transactions and conversion to and from cryptocurrencies may require standardisation to enhance adoption. Nevertheless, the widespread use of mobile money in various low-income and middle-income countries suggests that the acceptance of electronic currency is already present, potentially allowing for greater uptake with comparable platforms.

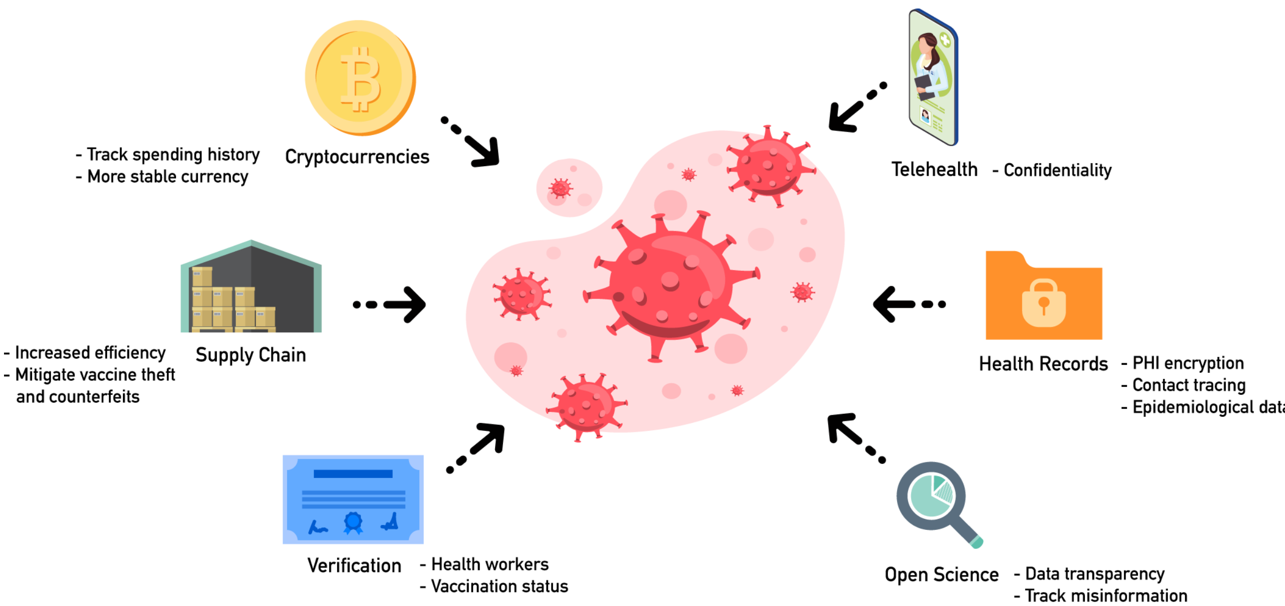

Figure 2 Opportunities for blockchain in the COVID-19 pandemic. PHI, patient health information.

A major benefit of cryptocurrencies is the disintermediation of transactions, allowing for transactions to take place without a middleman, such as a bank or credit card company. This results in reduced costs (eg, minimal transaction costs and no currency exchange costs), increased efficiency (eg, less processing time) and greater transparency as it prevents the risk of double-spending or counterfeiting, whereby nefarious individuals take advantage of the lag in third-party verification and quickly 'double-spend' funds in two separate transactions. With cryptocurrencies, the blockchain to which a transaction is added quickly and securely verifies the validity of the transaction, on which the specified block is added to the blockchain. In other words, a transaction can only occur if a majority of the network's nodes endorse the transaction.

The role of cryptocurrencies in global health is particularly important.[9] First, with numerous global health funding streams, significant amounts of money are lost due to transaction and administrative costs. Cryptocurrencies can bypass much of these costs, thereby saving money for the original purpose of global health funding and improving progress towards global health targets. For example, the World Food Programme is projected to save US$150 000 in transaction costs each month with the introduction of blockchain-based transactions to local communities.[10] Second, corruption remains a problem around the world. Blockchain-based cryptocurrencies can ensure transparent verification of transactions as well as a traceable transaction history over time and across stakeholders. Third, their security can improve trust in banking and global health financing systems, while giving financial credibility to anyone with cryptocurrency funds, thus making anyone with a verifiable cryptocurrency balance a trusted payer. Conversely, it is important to be cognisant of the potential surge of crypto-colonial practices in global health and international development in line with past colonial and neo-colonial activities that advance capital interests abroad.[11] This may present itself as green investments, investment inequalities and power asymmetry as a result of data colonialism. Despite being a distributed ledger, blockchain may thus not be full without geography if not configured appropriately.

Cryptocurrencies showed to have a relative hedging role against pandemic-related uncertainty, unlike stocks and broader economies, especially as the pandemic had a positive impact on cryptocurrencies' market efficiency.[12 13] Although volatile in the short-term, cryptocurrencies are less prone to inflation and deflation. These trends suggest that cryptocurrencies may serve as more stable financing mechanisms during times of great uncertainty. Moreover, blockchain-driven financing mechanisms have proven efficient and more secure. For example, Ant Financials' Ant Duo-Chain is a blockchain-enabled supply chain finance platform that has allowed small and medium suppliers to get instant credit despite being perceived as high-risk by banks; by selling invoices to banks, which collect money from corporate customers, the platform allows for higher liquidity to be given to suppliers.[14]

SUPPLY CHAINS

Supply chain management is another growing sector of interest for blockchain implementation due to its ability to reduce intermediaries, buy from the source and better track supplies. Supply chain inefficiencies, either due to delays or loss of products and money, have been widely reported in global health.[15 16]

Smart contracts, which pose conditions to be met to automatically execute a transaction, can be leveraged for innovative supply chain management, as they replace intermediaries or middlemen and ensure automation, reducing potential mismanagement and costs as well as improving efficiency. Intelligent smart contracts can be structured to ensure automatic adjustments of costs and compensation to members of a supply chain, which was normally performed by third-party coordinators.[17] In addition to improving overall supply chains, it may also improve the operations of and trust in charities donating supplies to low-income and middle-income countries or disaster-struck areas. Device donations are often reported to be dysfunctional, which may cause safety issues with their use in clinical care if not detected in time.[18] Creating a mechanism to track devices and use smart contracts could increase a sense of accountability by donors and increased trust by recipient centres. Similarly, with growing attention for postmarket surveillance of medical devices due to stricter regulations, a secure mechanism for verification by designated bodies would promote more adequate review of devices once on the market.[19]

With a global race to vaccinate the world, there is an opportunity to leverage blockchain-based supply chains to mitigate inefficiencies, thefts and counterfeits of available vaccines. Similarly, storage temperature and other atmospheric data can be recorded on a blockchain, which provides distributors' and consumers' information about the integrity of the supply chain and can help identify weak points.[20] Smart contracts could be introduced to automatically pay infringed parties if issues were to occur. Furthermore, personal protective equipment and ventilator shortages during the pandemic have illustrated flaws in current supply chains, which have been unable to detect in real time where resources are most needed. A decentralised manufacturer, Rapid Medical Parts, allows customers to order and three-dimensional (3D) print parts when and where they need them. They use a blockchain-based decentralised platform to ensure their design and printing instructions cannot be manipulated.[21] With vaccines increasingly being distributed worldwide, smart contracts could be applied to reward providers on administering and/or receiving the vaccine and provide feedback to distributors to automatically procure more vaccines to optimise real-time distribution.

HEALTH RECORDS AND INSURANCE

Health records storage has been subjected to risks of privacy breaches, either by a loss of physical patient files or unauthorised access to electronic health records. During the first half of 2019, nearly 4000 breaches were publicly disclosed, which compromised over four billion records globally, several of which originated from the healthcare industry.[4] Through 505 healthcare data breaches, over 40 million healthcare records were exposed, stolen or illegally disclosed in 2019.[22] Across all industries, the healthcare industry is the most costly to recover from data breaches at an average of US$7.13 million per breach globally running up to as much as US$15 million on average in the USA.[23 24] Blockchain technology provides a more secure and transparent means of storing and analysing data, as the distributed nature prevents failure by a single central node and encryption takes place through complex algorithms that provide near-foolproof security towards breaches. In particular, blockchain can aid with the interoperability of electronic health records, to allow patients to see providers in different networks or health systems with their full patient health information. In the USA, full interoperability could save up to US$80 billion each year through reduced wasteful spending (eg, redundant investigations) and administrative costs.[25] Such interoperability can be linked with health information obtained from patients through wearables and self-reporting (eg, physical activity and diet) to create a comprehensive 'electronic health chain'.[26] Various hospitals in high-income countries are planning for such integration to improve the security and interoperability of patients' electronic health records.[27 28] In Toronto, the University Health Network, in collaboration with eHealth Ontario and IBM, launched a blockchain-based patient consent gateway in 2018, to allow patients to share electronic records with trusted health workers and assess which entities may have access to their records.[29] Similarly, the European Union developed the blockchain-enabled platform MyHealthMyData to facilitate information sharing between all authorised parties.[30] The use of blockchain technology in the context of health records can also play an important role in mitigating healthcare disparities. The widespread availability of trustworthy health records can allow for crucial information to be accessed by the healthcare provider and, therefore, improve health outcomes regardless of patients' health literacy levels, recall about previous medical conditions and active role in their medical care. Moreover, smart contracts are of potential for health insurance processing, whereby providers are reimbursed based on predetermined requirements such as diagnostic indications, treatment protocols and quality metrics. These accelerate reimbursements, which are a considerable administrative bottleneck in many health systems. Additionally, it can ensure price transparency inherent to blockchain technology. Nevertheless, for both health records and insurance data, it must be noted that such transparency can result in potential undesirable outcomes. For example, companies and private organisations may resort to soliciting patient data from patients themselves by offering payments in return for data. Thus, careful regulations must accompany the introduction of such technology in supporting health records and insurance.

During outbreaks and for other reportable diseases, more efficient (ie, faster) and more accurate (ie, less loss of data) reporting to the appropriate public health or disease control authorities can occur with fewer intermediary steps. Similarly, secure and rapid access to such real-time interoperable data can be highly beneficial for the development of diagnostic methods, therapeutics or more accurate risk predictions, and more reliable contact tracing.[31] The pseudoanonymity enabled by blockchain-based algorithms may increase uptake and acceptance by the public, while providing public health authorities with an effective tool to, for example, assess crowd sizes in public areas.[32] An open data hub, MiPasa, was founded by the enterprise blockchain firm HACERA in response to the pandemic, uniting the WHO, IBM, Oracle, Microsoft and various government agencies and international health organisations.[33] Specifically, MiPasa detects COVID-19 carriers and hotspots,and shares that data securely with the appropriate individuals and authorities through anonymous digital identifiers, allowing it to improve the epidemiological data gathered by the WHO and national public health agencies.[34]

TELEHEALTH

Geographic barriers, travel costs and time inefficiencies, along with improved technological resources, have resulted in a rapid surge of telehealth modalities, further propelled by the current pandemic. In 2019, the global telehealth market size was valued at approximately US$61 billion, with projections of reaching US$560 billion by 2027.[35] The use of telehealth comes with a concern for ensuring the protection of patient health information; secure blockchain-powered platforms could help reduce this risk.[36]

In South Korea, the government has allocated US$3 million to fund blockchain trial projects in different industries, among which nearly one million was dedicated to a self-care management initiative for patients with chronic heart disease.[37] Over 6 months, 100 patients were requested to remotely input health metrics related to physical activity, diet, blood pressure and glycaemia, which are combined with previous health data and artificial intelligence to predict the occurrence of cardiovascular or other health events. This may reduce the burden on patients and providers by limiting the need for physical follow-up consultations and unnecessary investigations and is projected to be expanded to half a million patients with chronic diseases in 2021.

During the pandemic, telehealth has been increasingly implemented due to social distancing measures. McKinsey & Company estimated a growth from 11% to 46% in US consumers' telehealth adoption, with projections of becoming a US$250 billion industry after the pandemic.[38] The expectation is that telehealth will continue to play an important role in healthcare. Concerns regarding confidentiality will remain, and so will the opportunity for blockchain-powered platforms to be implemented.

IDENTIFICATION AND VERIFICATION

Core to blockchain technology is its ability to identify, authenticate and authorise information. Suggestions have been raised for its use in future e-passports, which can prevent fraud with personal documentation as well as more rapid border control processing.[39] In healthcare, blockchain technology may be used for the credentialing and verification of credentials of health workers, organisations and institutions, as well as providing proof of ownership, such as for the verification of drugs' or devices' producers. The Council for Affordable Quality Healthcare estimated that over US$2 billion is spent each year to maintain provider databases in the USA, yet, according to the Centers for Medicare and Medicaid Services, over half of the directories still have inconsistencies and inaccuracies.[40 41] These are costs and inefficiencies that could largely be prevented with the introduction of blockchain technology.

Several such opportunities have already been leveraged. For example, in veterinary medicine, IBM has developed a blockchain-enabled platform to allow for the creation and storage of United States Department of Agriculture (USDA) certificates.[42] Additionally, IBM developed a Mobile Identity platform that has been proposed to support the adoption and secure vetting of mobile driver's licenses.[43] This can be extended to include a degree or licensing verification in healthcare to prevent the occurrence of falsified degrees or licenses and optimise the maintenance and updating of provider directories. Massachusetts Institute of Technology and Learning Machine, now Hyland Credentials, partnered to create tamper-proof and verifiable digital diplomas using the same blockchain used by Bitcoin.[44] Blockcerts allows authorised users to create and issue certificates (eg, university with private key, which is transferred to the graduate once added to the blockchain) as well view and verify certificates (eg, employers with public key that a graduate can share).[45]

Opportunities arise to track and verify vaccination status and to prevent fraudulent information like counterfeit vaccination cards. IBM has introduced its blockchain-powered Digital Health Pass for COVID-19, which allows users to store their digital health information and allows them to be verified by the appropriate instances (eg, company requiring verification to physically return to work).[46] Similarly, the International Air Transport Association is developing a mobile app to verify travellers' COVID-19-free status, which may be extended to include vaccination status and/or the presence of antibodies.[47]

RESEARCH, OPEN SCIENCE AND MISINFORMATION

The application of blockchain technology extends to academia. Typically, research registries are housed at central institutions, which act as the authority in coordinating data collection, transfer and analysis. These may be hampered by distrust, inefficiency, intentional manipulation or attacks of data.[48] Utilising distributed ledger technology, data are stored and processed on the premise of digital trust, whereby the network can automatically validate and store the data, whereas immutability and transparency are ensured. Moreover, encryption and hashing of data help ensure anonymity, circumventing privacy concerns surrounding patient health information of rare diseases or rare cases, which would otherwise be easily identified. Such infrastructure can be expanded to the existing large-scale databases, such as those maintained for quality improvement metrics and research purposes, and even connected with electronic health records. Similar advantages have been reported with the conduct (eg, protocol compliance) and analysis of clinical trials, as well as omics big data.[49–51] Furthermore, blockchain promotes the automation of consent-giving and may give rise to prosent, or 'the blockchain-enabled ability of all stakeholders in the research process to pseudonymously and proactively consent to data release or exchange under specific conditions, such as trial completion.'[52]

The manipulation of data and growing distrust of contemporary science has taken a central role in this pandemic, especially centred around hydroxychloroquine use and the associated Surgisphere scandal whereby data, published in two of the world's leading medical journals, turned out to be fraudulent.[53] The scandal exposed the flaws in today's peer review and scientific data use processes, requiring mechanisms to prevent manipulation and promote transparency.[54] Open science initiatives can be facilitated through distributed ledger technologies, which can be encouraged by journals by providing a 'license of reliability' to those that enable transparent data review, as seen with blockchain.[54 55] Further opportunities may present for improving the transparency and validity of systematic reviews and meta-analyses, which are commonly at the basis of scientific and medical guidelines in addition to expert panels.[56] Distributed ledger technology can indirectly also enable a reduction in predatory journals and their activity, a common problem in today's academic ecosystem.[57] Journals' veracity and best practices are guided by the Committee on Publication Ethics; however, predatory journals, which are journals that take advantage of vulnerable authors to publish articles after minimal or no review against a fee, violate many ethical practices.[58] Predatory journals are often established with no true academic ambition, actively soliciting submissions via email and social media and already generating tens of millions of dollars over time.[59] Blockchain-based technology could enable verification of the nature and activity of journals, trace funds (eg, article processing charges paid by authors) and identify the responsible individuals behind such practices.

Blockchain-driven media can further reduce the production and circulation of misinformation by ensuring the traceability of information sources such as false infographics or manipulated images.[60] The spread of misinformation has been a particular problem during the pandemic and is expected to be propagated with the rollout of vaccines.[61]

LIMITATIONS AND CONSIDERATIONS

Blockchain is no panacea, and many healthcare executives remain sceptical of its near future given the barriers to implementation.[62] Inevitably, various considerations come into play. The costs associated with the infrastructure are substantial: for example, the IBM Blockchain Platform, using the IBM Cloud, is priced at US$0.29 per allocated central processing unit (CPU) hour, which may quickly add up to US$1 00 000–2 00 000 for startups and tens of millions of dollars for large enterprises.[63] First-generation blockchain technologies, such as Bitcoin, are associated with substantial waste of energy due to the requirement of high CPU power across all network nodes. Overall costs vary widely depending on anticipated transactional volume (and thus computing power) and must take into consideration the necessary infrastructure and the need to create private and permissioned blockchains. Similarly, the throughput (ie, speed at which transactions occur) is vastly lower on blockchain compared with contemporary platforms: Bitcoin processes approximately seven transactions per second, while VISA and Twitter, which do not use blockchain, process up to 15 000 per second.[8] Nevertheless, newer cryptocurrencies, such as Ethereum (second generation) and Solana (third generation), are built on faster blockchains that approach the speed of non-blockchains platforms. However, increased throughput will be necessary to promote wider adoption. Moreover, technical expertise is needed to ensure optimal use across the network. Large files, such as diagnostic imaging in patients' health records, require substantial computing power to be encrypted and storage space, which reduces the ease thereof on blockchain technology; thus, it may not be a one-size-fits-all for healthcare data. Finally, blockchain technology is highly reliant on proper internet access, which widely varies worldwide. While half of the world's population is estimated to have internet access, including 86% across high-income countries, it is as low as 16% of the population in low-income countries.[64] Disparities in internet access are observed across different race and ethnicity groups. In the USA, Hispanic individuals have 63% lower odds and non-Hispanic Black individuals 49% lower odds of having internet access than White individuals.[65] Although governments, private industry and non-governmental organisations are rapidly expanding internet access globally at increasingly lower costs, such infrastructure will be foundational to introduce and scale any internet-based technology.[66] Otherwise, health disparities may be exacerbated, benefiting only those able to access and use digital health solutions.

Meanwhile, regulation and legislation are lagging behind the still limited science surrounding blockchain technology, especially in healthcare. Specifically, the current body of research is skewed towards Bitcoin and theoretical descriptions in dominant sectors, whereas other sectors and implementation are rarely described.[67] Detailed case studies are even more scarce.[68] The resulting lag in legislation relative to technological developments may prevent mass adoption of blockchain, as sectors and individual organisations may not be willing to take the business risk associated with blockchain investments given regulatory uncertainty.[69] Further, for smart contracts, it must be noted that in rare situations contract conditions cannot always be met, for example, due to unforeseeable events (ie, force majeure clauses). Inherently, smart contracts apply blockchain-enabled immutable processes that are less flexible than contracts with centralised oversight and flexibility. Thus, excuses for non-performance—either by mutual agreement or predefined by local law—must be embedded in smart contracts' code to pre-emptively allow for such exceptions to take place and avoid automatic transactions when not appropriate. Finally, there are legislative limitations to the scalability of blockchain technologies due to differences in privacy and data use regulations across regions as reflected by the recent General Data Protection Regulation introduced in the European Union.

CONCLUSION

The opportunities for blockchain implementation in healthcare and global health are plenty and can enable more secure, efficient, and cheaper data storage, analysis and transfers. However, blockchain technology infrastructure remains scarce and technical knowhow is necessary to properly implement this. Increased investments and education are needed to successfully implement blockchain in modern medicine and global health to better address health disparities and mitigate the impact of future pandemics and natural disasters.

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