Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
CHAPTER FOUR

Blockchain: Opportunities in the healthcare sector and its uses in COVID-19

Senthil Kumar Arumugam\textsuperscript{a} and Aarti Mehta Sharma\textsuperscript{b,c}
\textsuperscript{a}Department of Professional Studies, School of Commerce, Finance and Accountancy, Christ University, Bangalore, Karnataka, India
\textsuperscript{b}Symbiosis Centre for Management Studies, Bengaluru, Karnataka, India
\textsuperscript{c}Symbiosis International (Deemed University), Pune, Maharashtra, India

1 Introduction

COVID-19 started from (Fauci et al., 2020; Mishra et al., 2020) Wuhan in China in December 2019 and brought suffering and death to the entire world. There have been two waves so far, and the world is bracing for a third wave. A report by the World Health Organization (WHO, 2021a) in May 2021 said that the rate of COVID patients and fatalities have been more in the South-East Asian countries, particularly devastating for India. As the pandemic rages across the world, it has pushed governments to re-examine their healthcare budgets. Out of 223 countries affected with Coronavirus pandemic at the global level as of June 2021, the top two countries most devastated by the pandemic are the two biggest democracies globally: the USA and India. While the USA suffered in the first wave, India suffered a lot in the second wave during April–June 2021, the second worst-affected country by COVID-19. Table 1 exhibits that as of 15 June 2021, the USA had positioned at the top with 33,140,498 COVID-19 cases, followed by India in second place with 29,510,410 cases at the world level. According to the WHO COVID-19 statistics, on 15 June 2021, 175,847,347 confirmed cases include 3,807,276 confirmed deaths and 2,187,874,534 Vaccine doses administered at the world level. As of 15 June 2021, 29,510,410 confirmed cases, 374,305 deaths, 238,840,635 vaccine doses administered in India (WHO, 2021a). Fig. 1 shows the number of global-level novel Coronavirus deaths at the start of each month from Jan 2020 to July 2021.
The WHO also said (WHO, 2021b) that the virus will evolve again. The third wave is expected to hit India by October 2021 (Sharma, 2021a). Thus, it is even more important now to prevent transmission, reduce the occurrence of mutations, and speed up vaccination. If the present disease becomes uncontrollable, it could spread to the animal populations, worsening the fight against the virus. In Vandalur Zoo, Chennai (a city in South India), a nine-year-old lioness died of suspected COVID-19 infection and confirmed positive in other nine lions (Oppili, 2021). Many countries, such as India, the USA, UK, etc., have had to impose lockdowns in their countries, leading to massive economic and social imbalances (Mishra et al., 2020). Governments and societies will take a long time to recover from these imbalances. In India, especially, there are families where both parents have

| Top 15 countries | Country name               | Total number of positive COVID cases | Total number of deaths |
|------------------|-----------------------------|--------------------------------------|------------------------|
| 1                | United States of America    | 33,140,498                           | 594,644                |
| 2                | India                       | 29,510,410                           | 374,305                |
| 3                | Brazil                      | 17,412,766                           | 487,401                |
| 4                | France                      | 5,635,842                            | 109,512                |
| 5                | Turkey                      | 5,330,447                            | 48,721                 |
| 6                | Russian Federation          | 5,222,408                            | 126,801                |
| 7                | The United Kingdom          | 4,565,817                            | 127,904                |
| 8                | Italy                       | 4,244,872                            | 127,002                |
| 9                | Argentina                   | 4,124,190                            | 85,343                 |
| 10               | Colombia                    | 3,753,224                            | 95,778                 |
| 11               | Spain                       | 3,729,458                            | 80,465                 |
| 12               | Germany                     | 3,715,518                            | 89,844                 |
| 13               | Iran (Islamic Republic of)  | 3,039,432                            | 82,217                 |
| 14               | Poland                      | 2,877,608                            | 74,574                 |
| 15               | Mexico                      | 2,454,176                            | 230,150                |
| 16               | Ukraine                     | 2,223,978                            | 51,692                 |
| 17               | Peru                        | 2,003,625                            | 188,708                |
| 18               | Indonesia                   | 1,919,547                            | 53,116                 |
| 19               | South Africa                | 1,747,082                            | 57,731                 |
| 20               | Netherlands                 | 1,672,744                            | 17,711                 |

Data Source: WHO, 2021a. Coronavirus disease (COVID-19) pandemic. https://www.who.int/emergencies/diseases/novel-coronavirus-2019 (Accessed 15 June 2021).
died of COVID, leaving children as orphans. This issue has prompted the Prime minister of India to announce a scheme especially to look after these unfortunate children (TNN, 2021). The future will get even bleaker if the virus is not defeated. For this to happen, vigilance and healthcare are paramount, and so is vaccination. Experts say that the best hope for humanity is if whole countries are vaccinated swiftly, and social distancing is maintained. One way to ensure a quick and error-free vaccination process is by using Blockchain Technology (BCT). While some healthcare providers have been using this technology to maintain records and make supply chains agile, now is the time for more and faster absorption so that this disease can be defeated.

BCT became prominent when cryptocurrency came into the popular realm. BCT applies for various purposes that range from cybercash, financial trading and services, managing risks, trading and services, internet of things, etc., that benefit all sectors in the economy. The business sectors and service companies currently opt for this technology as the best option for accessing vital real-time information shown in a reliable format from trusted sources.
BCT provides authentication, security, transparency, trust, decentralized structure, and privacy for the data communicated through its digital blocks. BCT is otherwise known as “distributed ledger technology” (DLT). It is a secure way to collect, keep and transfer healthcare and its related financial records. It provides a path for individuals to engage openly with others to perform their day-to-day business tasks, services, and fund transfer (Furst, 2020). The present chapter examines the technology, its uses and explains the enormous applications of BCT in healthcare during the COVID pandemic period. It also focuses on the future of healthcare in the blockchain world.

2 Chapter objectives

The WHO has invited researchers and professionals worldwide to accelerate Research and Development (R & D) for providing solutions in “catastrophic” occasions like pandemics, natural disasters, etc. There is an immediate requirement to collect data quickly, share the most advanced existing knowledge, and offer preventive measures quickly at all parts of the universe during outbreaks. In healthcare, it is essential to monitor patients affected during pandemics, tests, medicines, administering vaccines, fees payment, location of medical facilities available, hospital resources, etc. These should be recorded up to date and should take action at the zero-time delay to prevent further pandemic waves. Coordinating all activities globally and integrating and sharing information transparently, the usage of emerging technologies and their applications in healthcare is very much needed, specifically BCT. This chapter aims to identify opportunities in the healthcare sector where blockchain can be applied, particularly in the COVID-19 scenario. Also, it discusses few use cases in which BCT is effectively implemented. The chapter also analyses the implementation challenges in healthcare and how BCT shapes the healthcare industry’s future?

3 Research design

The chapter is formed as a meta-synthesis. Secondary data sources such as journal and news articles, reports of Governments, and other recognized organizations were collected and analyzed. In addition, interviews with healthcare officials and blockchain experts were conducted to derive more qualitative inputs related to recent disputes in the healthcare industry and the practicality of emerging technologies.
4 Blockchain technology (BCT)—An overview

In today’s world, we maintain records of all kinds of transactions—transferring money, buying goods, paying for electricity or other utilities. Keeping these records is essential for business as they are the data points that lead to better customer service through better recommendations; they help companies forecast the demand of existing products and pave the way for developing new products. This way, they help businesses prepare for the future. Most of these take time to create and maintain and be error-free. If we transact today, the transaction will occur immediately, but the settlement will happen later. For example, if we sell equity stock today or buy mutual funds today, we can sell instantly, but the payment will take time. If we want to sell a house, the negotiation will be done quickly. Still, the registration process (verifying and registering the change in property ownership) will take time and involve lawyers and government employees. Each party maintains its ledger at every stage and is not privy to the other parties’ ledgers. This makes the whole process slow and insecure as only each person at each level is privy to their ledger data. On the other hand, if the same transaction were recorded in the blockchain, details of the same such as price, asset, and ownership, would be recorded, verified and settled within seconds across all levels.

Before going any further, it makes sense to understand blockchain (BC) and why it is gaining in popularity. The blockchain came into an alternative to make payments securely and without needing a bank to mediate. The father of blockchain technology, nicknamed Satoshi Nakamoto, described it as “blockchain is a completely peer-to-peer version of electronic money that allows online payments to be sent directly from one party to another without going through a financial institution” (Nakamoto, 2009). It can be said to be an offshoot of people getting used to the internet, shopping, entertaining, communicating, and most of the time for digital cash transactions. “A blockchain is an irreversible distributed ledger that only adds data with a time-ordered set of facts known as transactions. These transactions are further clustered into blocks and structure a cryptographic hash chain. This process is termed a blockchain (Luu et al., 2016). We can think of it as a distributed system for taking down patient details and managing them. The peer-to-peer-based blockchain records are shared, immutable (cannot be changed), and stored in an append-only digital ledger.
There is no single authority in the blockchain. It is an established crypto-

technique that allows each node (participant) in a chain network for inter-

acting, storing, exchanging, and viewing block information with no prior

“trust” between the nodes. Before adding data into the block, miners verify

and authenticate the data in the network. The process in the network is well-

known by all nodes involved in it (Krawiec et al., 2016). BC is a cloud-

centered system storing information and most famously used for

cryptocurrencies like Bitcoin, Ethereum, etc. It promotes flexibility, secu-

rity, and faster data transfer and sharing (Sahu, 2020; Xu, 2016). While the

BCT was proposed to store digital data in 1991, it became famous for for-

ming Bitcoin. The reason was that once data shared on it; it cannot be chan-

ged. Given in Fig. 2 is a simple transaction made by using BCT.

Each block is a structural and functional unit consisting of transaction
details, the hash value of current, and the previous block. A hash value

can be considered a digital signature unique to each transaction, hence each
block. The hash of the first block is known as “genesis,” and this hash is pre-

fixed to all new transactions in a new block, thus creating a unique hash.

Each block is connected to the next one, and it thus forms a chain.

Depending on the usage of the BC system, the data in a block may differ.

Most data in a block are a ledger of transactions. For example, suppose

![Fig. 2 The flow of a transaction made using a blockchain.](image-url)
Person A wants to sell Product Z to Person B. In that case, the block will contain data on the seller, the buyer, the good, the time of the transaction, the transaction fee and the digital signature of the transaction with a unique hash. A cryptocurrency, like Bitcoin, works based on BCT, which stores data known as transaction information. A hash is generated in the block for this digital transaction information similar to a fingerprint. Cryptocurrency platforms use different types of hashing algorithms. For example, the algorithm, namely “SHA256,” is used by Bitcoin, Ethereum uses the “ethash” algorithm. It mimics a linked list structure, except instead of pointers, it uses hashes. The next block of the chain and other blocks too do not point to this one. If anyone in the BC alters data, the unique hash value of the particular altered block also changes automatically. Hence it proves as a secured system. Users identify tampering through hashes. A hash function converts the different types and length of inputs into a fixed-length output called “hashhash.” The hash function generates a fixed hash size even though the original data set size varies. The set of lengths may be the bit of 32 or 64 or 128 or 256 length (Frankenfield, 2021). Further security is added by users having public and private keys.

BCT uses the peer-to-peer structure, and every user in this group receives a copy of the transaction in BC. If anyone tries to tamper with the network, that person should change the whole chain’s information. It is not possible to alter and break the security. So, the technologists say BCT is the emerging technology for secured data transfer. There are many advantages of working with a BCT. They are as follows:

(i) BC reveals the history of data. Users get only the updated data in traditional data structures, but while BC, users can retrieve the entire data path from origin to end. The whole track is visible in BC. It is complicated for anyone to change the data. Hence, it is “immutable.”

(ii) BC is decentralized. It stores information in a shared distributed database, and there is no exclusive database; however, participants can take any number of copies of it. Again, this adds to the security of the data, and more people can benefit from it.

(iii) There is no single authority to manage the database in BCT. All nodes of BC can receive all copies of transactions and updated them every time.

Different authors have described this technology through different characteristics. According to Monttechi et al. (2018), the essential properties of BC are that it is decentralized, verified, and immutable. The network does not rely on any central administration. When any transaction adds to the chain
database, the member in the peer-to-peer blockchain network receives a copy of it. Before sharing data to members in a group, the members first approve the transactions and sign them using private keys. It is immutable because its consensus method allows creating a new block containing many transactions that all network users can verify. If they disagree on the transactions, then they cannot add the block. Hence it is known as a consensus. According to Ali et al. (2021), the main characteristics of BC are trust and decentralization. They say that a “proof-of-work protocol” secures the network and eliminates outsider’s participation to check and enter the transaction. This protocol makes it difficult for hackers to attack the system and makes it virtually unhackable. The main features of BCT are “persistence,” “anonymity,” and “auditability” (Singh et al., 2021). BC looks like a ledger where every transaction between parties is recorded and uses cryptography for data security. It has a “consensus” procedure for warehousing, even one copy or multiple copies of registers and new entries (Kuner et al., 2018). Transaction data are stored in the block format and not written over. There is no central administrator for the administration of this block data.

Recently, BCT applies across all fields, such as selling art and tattoos as non-fungible tokens (NFT’s) and sell items to gamers (Chakraborty, 2021). The banking and finance industry, namely HSBC, Visa, and Barclays, use it. InBev and Unilever use it for their supply chains, Pfizer and CDC use its healthcare, the Netherland government for border control, AIG for insurance, DeBeers to monitor diamonds’ movement. Other companies that have absorbed this are the government of Dubai, Siemens, Nestle, Sony Music, etc. The number of users is growing day by day and contains the who’s who of the business world and governments worldwide who need fast and transparent systems (Iredale, 2020; Lauren et al., 2021; Zago, 2018).

In simple, BC is a system that stores and shares various types of secure information among participants in the network. Each block in BC has two parts, in which the block’s data stores in the first part, and the other part contains a dependent link. Without a third party’s intervention, participants (nodes) of the network add and transfer the data to others. This technology provides solutions for enhancing healthcare applications such as mobile healthcare applications, medical device monitoring, managing electronic data and records, data generated in clinical trials, patient insurance details, etc. Before December 2019, there were only limited researches in blockchain healthcare applications. However, recently, blockchain specialists are trying to solve all healthcare issues using BCT collaborating with the hospital industry.
5 Challenges and opportunities in the healthcare sector

Today, citizens have access to multiple healthcare options; for example, we can use smart watches, smart bands, fitness apps, online doctor consultations, face-to-face doctor consultations, medicine delivery apps, and sometimes stints in hospitals. All these are nodes in our healthcare system and are disconnected from each other. If they could be bound together chronologically, it would be beneficial to patients and doctors alike. However, the absorption by healthcare leaving a few has not been great, whereas considering that healthcare is such that there is a need for a distributed ledger, it should have been much more. In today’s world, a single patient in India generates records in multiple places. Few examples, on apps like a Practo for doctors’ consultation, on watches and bands like Fitbit and Redmi, on health apps on the mobile like a Pacer, HealthifyMe, etc., and of course on visits to hospitals. The research survey of KPMG (Arsene, 2020) said that acquiring healthcare data is challenging, disorganized and involve huge costs. Around 38% of the leading health sector’s Chief Information Officers have expressed that efficient management of electronic healthcare data and records are the priority of their budgeting planning and consideration in the decision-making process. When healthcare personnel start to maintain and manage these electronic records using BCT, it helps to improve accessibility by all parties, and clients can share documents securely, enlarge interoperability, follow compliance, and valuable in so many ways.

While the healthcare domain needs to share data across all stakeholders to function efficiently, it is challenging to follow them because of an incorrect positive result, replicate records, lack of privacy, etc. (Furst, 2020). Furthermore, lack of trust hinders transparency and efficiency as the stakeholders are reluctant to share data as it may impinge on privacy. An immediate solution to this is to use blockchain technology (BCT), as it allows competitors to transfer patients’ details simultaneously to maintain their competitive freedom and privacy. Due to these attributes, it has emerged as a solution provider for various issues in the COVID-19 pandemic and business sectors, giving much importance to healthcare-related data sharing.

There have been malicious attacks on healthcare systems in India (Service, I. A. News, 2019) and abroad (Combs, 2021; Davis, 2020). Hackers have accessed millions of patients’ records stored in traditional databases. As governments rush to safeguard and vaccinate citizens against Coronavirus, they use schools, parks, etc., along with hospitals. These temporary arrangements result in security protocols getting strained and making it easier
for criminals to hack patient data. Earlier research papers (Mathew, 2019; Xu, 2016) have pointed out that BCT can help prevent malicious attacks, and the healthcare industry now realizes the power of BCT. It is now that BCT can be used to avoid hacking, sharing data securely, and thus providing help and relief to citizens.

Currently, the healthcare industry faces the most significant challenge due to counterfeit or fake drugs plaguing the pharmaceutical supply chain. Poor manufacturing procedures, inadequate storage, medication theft, and the market penetration of poor-quality/counterfeit items in gray markets are all factors that contribute to fake/compromised medication. The World Health Organization estimates that the black-market drugs business is approximately seventy-five billion dollars (Arsene, 2020), but the actual value might be far higher. This is especially true in nations like Bangladesh, where they are spending vast amounts on importing medicines. This is not exceptional to developed countries. Almost all countries are affecting by the healthcare supply chain process due to fake drugs. The Food and Drug Administration issued a caution notice in 2012 to more than a thousand healthcare institutions and health practitioners who may have been victims of bogus medication rings. They were informed, in particular, that they may have been supplied counterfeit drug “Avastin,” one of the most famous anti-cancer treatments on the healthcare market. The BC technology almost fulfills every criterion of FDA compliance such as product authorization, tracking, details of suppliers and agency, drugs verification, etc.

During the pandemic period, the patients’ detail from around the world should be available at shared commonplace for enabling the research work by the researchers. The clinical test needs accurate patient details for new vaccine development. The accuracy of research data depends on the healthcare intermediary who provides it. Most medical companies are not sharing their clinical trial details with others and should adhere to the ethical and regulatory requirements. BCT offers a solution to this problem. The data are stored in the common shared database. Any parties in the network can access the decentralized, transparent data.

The governments of the top two COVID-19-affected countries, the USA and India, have decided to spend more on healthcare. The US plans to carve out 20% of its GDP on this field (Daley, 2021), and the Indian government plans to spend 2.5% of its GDP on healthcare (MoF, 2021). This budget is nearly double what it had spent in the previous year. However, as the healthcare industry faces data breaches and problems with supply chains and maintaining patient records, issues arise in government and healthcare institutional administration and successful treatment.
6 Implementation of BC in developing and developed nations

While major business applications will be the same across all countries, it is interesting to observe the differences in BTC adoption between developing and developed countries. Blockchain consumes a lot of electricity; hence adoption in developed countries will be faster (Knowledge@Wharton, 2018). However, developing countries like India, Kenya, Estonia, etc., are highly interested in its applications for social good. Governments are exploring its wide-ranging applications like maintaining land records, keeping accounts of payments, supply chain management, etc. Andhra Pradesh, a State Government of India, is experimenting with maintaining records for land titling with blockchain. Governments of developing countries use blockchain to keep records in land titling, land ownership, healthcare, supply chain, payments, banking and financial services, agriculture, etc. (Martindale, 2018; Zambrano, 2020). As given by Transparency International (2020), a quick look at the most corrupt countries shows that most developing countries are also very corrupt. As blockchain is a technology wherein records once entered cannot be changed, this technology will help root out corruption and improve lives. The Department of Health and Human Services report, United States said that more than five million patients’ healthcare records were breached in 2017 (Ugalmugle and Swain, 2019). Therefore, governments that want to do well for their populations examine the benefits that BTC will bring to its citizens. BCT provides enormous opportunities in the healthcare sector of developing and developed nations that will take time to implement. Organizations of these nations should face many technical, institutional, and behavioral challenges before BCT implementations.

The following are the few major challenges faced by developing countries.

- Lack of technical infrastructure for BC implementation
- Shortage of skilled BC professionals
- Absence of essential governing norms and regulatory procedures
- Concerning audit compliance
- Distrust among users and lack of awareness of BCT
- Lack of ability to bring the network together
- Inability to scale
The following are the driving needs of BC implementation in developing countries.

- Rising the risks of fake medicines
- Increasing the rate of breaches of medical data and records
- Increasing of Internet of Things (IoT) applications in the healthcare industry
- Reduction of cost in various healthcare
- Cost-savings in several healthcare functions
- An increasing need to secure medical data
- Rising demand for storing healthcare data
- Rising need to integrate devices and stakeholders

Implementing BC can bring significant benefits to the healthcare industry of developing nations by providing relief for organizations from corruption, reducing intermediaries’ prices, and increasing trust among parties involved in medical businesses. The Government of Uganda has collaborated with Medi-connect, UK, a blockchain-based solution provider, to avoid the risks of receiving fake medicines during the supply chain. The BCT in healthcare market share is mainly contributing by pharmaceutical companies, healthcare payers, and healthcare providers. The Global Market Insights Inc. report 2019 said that the BCT in the healthcare market in Canada is estimated at 69.9% Compound Annual Growth Rate (CAGR) during 2019–2025. In 2018, the revenue of the BCT healthcare market in Germany was about USD 2.8 million (Ugalmugle and Swain, 2019). The investment made by start-up companies and the government in implementing BCT is a significant factor for the growth of the healthcare market in developed countries. An agreement was signed between the Gustave Roussy Institute, a foremost European cancer institute, and Embleema Incorporation in March 2019 for BCT-based clinical research and the secure transfer of healthcare records. According to the PwC Global BC survey (PwC, 2018), the United States (29%) was the most progressed region in developing BC projects than China (18%). However, China (30%) will most implement BC-based projects in 2023, followed by the US (18%), Australia (8%), India (6%), Hong Kong (5%), Denmark (5%), Japan (4%) and UK (2%).

7 Blockchain: Uses/applications in healthcare

BCT can correctly transform the healthcare sector includes medicine discovery, development, preclinical research, clinical research, and supply chain process. In the nineteenth centuries, scientists made many clinical trials
to find the effective one, and many failed to attain the Food and Drug Administration (FDA) approval stage. The reasons for the failure are pharmaceutical institutes are not acquiring the necessary patient data in an era when people do not trust them.

If BCT implemented well, it could be an excellent solution for enhancing data provenance, integrity, functionality, and, of course, security of a pharma supply chain. The uses of BCT in the healthcare industry are explained below. Fig. 3 also illustrates the various benefits and applications of BCT during the COVID–19 pandemic.

**Secured data sharing:** A recent report by the European Union Blockchain forum suggests that with this BCT, the patient will own the data and decide whether to share it or not. Also, it can be used for combating the virus by the governments (EUBlockchain, 2021; Lyons, 2020). In our world today, with the technology available, doctors, nurses, and health professionals are limited in the level of care they provided. This is due to the inability to view the complete health records. Medicalchain, a healthcare product company, has introduced a blockchain-based product for quick access to health records. This product keeps electronic data safe and secure in blockchain technology. The BCT layer in the Medicalchain product hosts limited non-personal information. This information access as pointers to

![Fig. 3 Uses of BCT during COVID-19 pandemic.](image-url)
writing the system into encrypted health records. These records help hospitals, universities, and nonprofit organizations regulated and handle sensible data. Only after patient’s authorization can one unlock their health records and view the mobile interface. But Medicalchain is much more to view patient’s health records using the telemedicine concept available in their device. The doctor can check the patient’s medical record and access his medical history. It permits the doctors to access life-saving information with managing vulnerable or unconscious patients. Medicalchain provides peace of mind, and the patient can feel safe, and health data is accessible by the doctor when it matters most.

Secure data of patients: As patients combine data by going to hospitals, consult online or through apps, use fitness apps, etc., they will generate more and more data. This data has to be secured. Last two decades, the world community has an outburst of medical-cum-health related technologies, from maintaining data in electronic format to the Internet of Things (IoT) health device to least-cost whole-genome ordering. The data collected from these devices have met silos primarily in combining the above data sources. BurstIQ, the US-based company established in 2015, solves the silos of integrating data sources in the healthcare industry through blockchain. It creates a path for an end-to-end BC-enabled system for managing big data using BC, adopting cognitive technologies for obtaining data, getting consent and sharing among participants globally, and revenue generation. Similarly, many companies Medicalchain, Factom doing healthcare services using BCT (Daley, 2021; Lyons, 2020; Tandon et al., 2020). Table 2 explains the role of companies in healthcare applications based on blockchain. Healthcare is personalized to each individual based on the beneficiaries’ sole genetic, medical, demographic profile, and socio-economic conditions. Healthcare will be available to every place, every individual regardless of the person, location, and money. These companies remove all hurdles in healthcare data management, and it connects all healthcare industry stakeholders at the global level.

Share databases and thus streamline costs: The technology’s decentralized nature establishes a common database for patients’ data that doctors and healthcare industry officials can access fast and provide effective treatments (Daley, 2021). BCT facilitates quicker diagnoses and personalized action plans (Daley, 2021; Tandon et al., 2020; Zheng et al., 2018). A few healthcare companies that implemented BCT are Simplyvital Health, Coral Health Research & Discovery, Robomed, etc.
### Table 2: Companies in blockchain-based healthcare.

| Company name | Nature of work |
|--------------|----------------|
| BurstIQ      | A US-based company established in 2015 provides an end-to-end BC enabled system that handles big data using BC. It performs data acquiring, authenticating and sharing among customers globally using cognitive technologies and facilitates revenue generation. |
| Chronicled   | The MediLedger Network is the ideal bridge between business parties, combining a secured peer-to-peer messaging network with a distributed BC network. It removes chargeback mistakes and disputes by administering agreed business rules. |
| Blockpharma  | This mobile app allows customers to check the legitimacy of the pharmaceutical package they buy in real-time. Medicine can be tracked from the factory to the point of sale. This app employs the most cutting-edge ML (Machine Learning) technology to increase the detection of counterfeit cases. |
| Tieron       | It creates technology and products that diminish the price and trust complication. It offers BC verifiable credentials, confirm the existence and correctness of electronic data and records and regulatory compliance. |
| DNAtix, Zenome, Luna DNA, EncrypGen | These leading companies have developed BC-based software for the analysis of human genome data. These data help for predictive analysis and to determine a data model for further product development. It assures the safest encryption system for all genome data for maintaining privacy. Some of the other notable companies in the genomic market are Nextcode Genomics, Murrieta Genomics, Gene Blockchain, Longenesis, SimplyVital Health, Neogen, Ripe Technology, Nebula Genomics, GSK, Genobank.io, Merck, Genomes.io, WuXi, Shivom, etc. |
| HealthVerity | It provides a BC-based centralized platform for the accurate data generation, distribution and secure management of patients, hospitals and healthcare data. It helps in predicting the practices and facilities to be implemented. It solves the existing problems relating to consent from patients in healthcare and supports “consent management.” |

Continued
Table 2 Companies in blockchain-based healthcare—cont’d

| Company name            | Nature of work                                                                                                                                 |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| Kalibrate Blockchain    | The firm has developed a BC-based power engine, “Universal Patient Index,” for form processing. It supports users in various healthcare activities by providing high clinical relevancy, blood testing, fill-up hospital intake forms and index healthcare. The patient can fill up the form in Kalibrate developed a mobile app and save timing and queuing when visiting hospitals. |
| TIBCO Software          | It has developed a BC driven smart contract system collaborated with Tennessee based “Change Healthcare” company. Their software automates the claim process of payment parties with verifiable and secure features. TIBCO Spotfire software provides data for clinical research, advanced analytics and visualization. |
| CVS Minute Clinics      | This US-based company’s BC smart contract system provides drug dispensing, compensation, and settlement processing.                          |
| Robomed Networks        | A Moscow based company is doing patient-hospital contracts using BCT. Its software facilitates self-executing contract rules, where the insurer, patient and hospital are part of BC. When the patient visits the hospital and meets a doctor, that incident automatically updated the ledger of BC. |
| Hashed Health           | They created a credential verification mechanism using blockchain for doctors and other clinical specialists to show that they are truly licensed to practice medicine. This company has collaborated with other companies such as Accenture, National Government Services, Spectrum Health, Hardenbergh Group, WellCare, and HealthLink Dimensions to create a BC-driven credential system. |
| IBM                     | The company has developed a BC system tie-up with insurers such as Aetna, Healthcare Service Corporation (HCSC), Anthem, and PNC Financial Services Group for digital payment operation and interoperability. |
| St. Joseph Health       | This company’s platform provides facilities for revenue cycle management using BCT. According to McKinsey Company, the platform uses smart contracts, DLT, and machine intelligence to help decrease inefficiencies in the healthcare revenue process. |
| Company name          | Nature of work                                                                                                                                                                                                 |
|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Guardtime             | It is a UK-based health technology company that has developed MyPCR and its partner Healthcare Gateway and Access Medical for improving medication adherence. It is the first BC driven PCR (Personal Care Record) portal. It efficiently manages the rights of General Data Protection Regulation patients’ data, integrates it and verifies them automatically. |
| Medicalchain          | It uses BC-driven HLT (hyper ledger technology) to access patients’ medical histories and help the healthcare companies and specialists with the other process. It ensures consent management, security, and transparency in the process, prescribes medicines, and solves patients’ doubts using their software platform. |
| Embleema and Hu-manity.co | In the medical field, the researchers typically approach healthcare marketing companies for their research analysis. These companies provide required patients details and issues. This process now simplified using BCT. Here, BC acts as an intermediator. It sells the patients data and their medical issue details to the medical researchers with the consent of the data owners in a suitable market platform. It provides relevant data to generate accurate test results. Also, it allows patients to store their data here and sell it to those who desire to purchase it. It promotes decentralization and selling patients’ data legally. |
| Change Healthcare     | The company has developed “the Hyperledger fabric driven BCT platform” for intelligent medical network, where patients/providers can effectively process their forms, audit the details, well known the status of the claim process. |
| FDA                   | The FDA’s platform helps patients safeguard their test results/trails of clinical activities, genomic and electronic medical records.                                                                                                                                 |
| DHL                   | It is one of the BCT-based biggest healthcare companies involved in tracking medical items from production to customer’s end-point (supply chain) and its partner company Accenture. As a result, businesses will finally eliminate any counterfeit medicine difficulties that they experience daily. |
### Table 2: Companies in blockchain-based healthcare—cont’d

| Company name                      | Nature of work                                                                                                                                 |
|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| Centers for Disease Control and Prevention | It offers new BCTs collaborating with IBM for improving the general health of American citizens. It provides security for electronic health records in the encrypted ledger system. |
| Pfizer                            | Pfizer is another most giant corporation that has used BCT. The CSBWG (Clinical Supply Blockchain Working Group), coordinated by Biogen and Pfizer, has produced proof of work for keeping patients documents and digital inventory management of medicinal items. |
| Anthem                            | In 2019, this insurance company used hyperledger fabric for customer services. Here, the patients can securely use their platform for sharing their medical records and other details. It is operating from Indiana. |
| Optum                             | The company started offering BC-based insurance services in 2018 using Ethereum based BC. Users can enter, share, verify, validate, and audit data within a network in this platform. |
| Samsung                           | Nexledger, a BC developed by Samsung SDS, South Korea based company, assists contracting parties in proving their identities and executing agreements. A consortium of eighteen Korean banks is already using the platform through an application called BankSign, which allows banks’ retail users to instantly prove who they are, even though they are not an existing customer when they visit there. Nexledger will assist patients in establishing their identification, reducing the time it takes for a health insurance claim to be processed. |
| Aon                               | This England based company is developing an “R3 Corda” BCT to speed up insurance procedures to avoid loss from hacker damages. It has developed a platform jointly with RenaissanceRe and EverestRe that will allow large reinsurers to share and cooperate their works on the same system. |
| Solve.Care                        | It offers a BC-based worldwide network for the administration and payment of healthcare services. Insurers, regulatory bodies, and healthcare institutions are among the firms that the corporation services. |
Manage supply chain and track the drug: How many of us understand medicine? How can we be sure that the product we are ordering is not damaged until it reaches the user? How to ensure that all drugs come from a genuine supplier? All of the above questions are essential concerns of the supply chain in the medical field that generally arise from everyone. BC is beneficial for making this drug supply chain transparent. BC has severe implications for drug supply chain management. And its virtual decentralization guarantees almost complete transparency in its operation (Daley, 2021; Lyons, 2020; Monttechi et al., 2018). Once medicine produced at the laboratory, information such as the place of origin, the number of quantities, supplier details, date of packing and rate of the medicine are stored in the BC ledger. As the drugs pass each route, their duration and the number of individuals involved in the supply chain have been recorded immediately in BC. Every action recorded in BC is known by each member of that BC immediately. BC helps to reduce costs drastically and avoid intermediaries and their prices.

Table 2  Companies in blockchain-based healthcare—cont’d

| Company name | Nature of work |
|--------------|----------------|
| Etheal       | This Hungarian-based firm has developed a BC-powered healthcare platform that aims to offer medical services more economical while eliminating inefficiency and lack of transparency. |
| Mimirium     | This software firm creates ecosystems with a primary focus on data gathering, processing, and securely analyzing the data. The firm has made four BCT-based products: personnel surveys, a network, a portal for health management, and smart city data. |
| Iryo Network | It is a database that stores medical health records on a decentralized basis. It promises to simplify data recording formats by combining fragmented data from numerous sources relating to a specific patient into a single file, obviating the need for fragmentation. |

*Source: Arsene, C., 2020. The Global “Blockchain in Healthcare” Report: The 2021 Ultimate Guide for every Executive. healthcareweekly.com https://healthcareweekly.com/blockchain-in-healthcare-guide/ (Accessed 14 December 2020); Iredale, G., 2020. List of Top 50 Companies Using Blockchain Technology. 101 blockchains https://101blockchains.com/companies-using-blockchain-technology/ (Accessed 30 May 2021); Lauren, D., Dent, M., Castillo, M.D., Hansen, S., Kaulin, J., Sorvino, C., Tucker, H., 2021. Blockchain 50. In: Castillo, M.D., Schifrin, M. (Eds.), Forbes, https://www.forbes.com/sites/michaeldelcastillo/2020/02/19/blockchain-50/?sh=77cf78b77553 (Accessed 30 May 2021).*
Currently, Chronicled, the San Francisco based company, supervise and maintain blockchain-based “MediLedger” in the healthcare sector. This foremost BCT model provides results for the medical supply chain issues, revenue management and eases trust and automation between companies. Similarly, other organizations are doing BC-based medical supply process such as Blockpharma, Tieron, and Centers for Disease Control and Prevention (CDC). In a recent poll (GlobalData Healthcare, 2021) conducted among pharmaceutical companies, the supply chain was where pharmaceuticals were expecting to get maximum gains from applying blockchain technology.

**Developments in genomics:** The genetic potential to improve human health previously a dream has become a scientific and financial reality with the development of current blockchain technology. Beneficiary spent about one billion dollars in 2001 on the human genome process. Currently, the same treatment costs only about a thousand dollars. Nowadays, many companies in the genomics market providing blockchain-based services. Ancestry, Gene blockchain, DNAtix, 23andME, Shivom, WuXi, Neogen, Longenesis, etc., are improving the lives of millions of people through DNA testing. This vast technological development has turned the market into a place where the public can sell their encrypted genetic data to create an extensive database. With this, valuable data is accessed quickly than ever before. All three companies, like DOC.AI, Encrypgen, and Nebula Genomics, use BCT to advance our knowledge of the essential structure of human life.

**Clinical trials:** Lyons (2020) believes that clinical trials are where blockchain companies could move faster and more securely. The same survey by global healthcare says that this is the second most important area in which blockchain is expected to impact (GlobalData Healthcare, 2021).

8 Blockchain: Implementation challenges and considerations in healthcare

Mainly speaking, two types of data can be maintained in healthcare management. “On-chain” data is directly stored on the blockchain. These are demographic data such as gender, date of birth, place of residence, etc. It does not identify the patient. “Off-chain” data refers to data stored in separate, traditional databases. The blockchain will have links to these sets of data. These data help identify the patient, and the patient can choose to share by using a key, for example, a patient’s x-ray or other diagnoses.
Tandon et al. (2020) conducted a systematic literature review and concluded that blockchain is being used and should be used to handle, process, store and share medical data and personal health records. This technology has added significant value through improved efficiency, access control, technological advancement, privacy protection, and security of data management processes. A conceptual model given by (Tandon et al., 2020) in their paper can be used in today’s time to fight the COVID pandemic successfully.

Once the information is generated, the data can be stored in a database using blockchain and the patient’s permission. This would help the patient get a holistic treatment without having to remember all past and present details. And also, this data would empower doctors to treat the patient better and faster. For a healthcare structure in India that is overburdened, this is like a dream come true. All this data needs to have a single administrator, but all the sources could keep adding information as blocks. Each source would have a key, along with the patient, and each would access the records.

The healthcare industry feels pain from transferring and interchange information due to complicated contracts between stakeholders. Inefficiency in the claim process, errors in documents, and payment process results in waste of money and loss of one’s life. After the blockchain transformation, all parties in the healthcare sector access and share the exact version of the information. Blockchain has four key dimensions, as explained in Fig. 4. First, the blockchain is an append-only distributed system of records shared across a business network. Second, smart contracts are business terms both embedded and executed in a transaction database. Third, all parties agree to the validity of a transaction committed to the blockchain. Fourth, it is a secure, authenticated, and verifiable transaction in a consensus mechanism.

Another pain point today is a pendant or denied claims due to missing or inaccurate information such as patient’s name, subscriber information, diagnosis and procedure codes. The term clinical attachment is a concept surrounding the need for additional clinical information when a payer adjudicates healthcare claims. The basic premise is that sending a claim without all supporting data is time-consuming, costly and challenging for all parties involved. Luckily a blockchain-enabled claims process provides transparency into the claim requirements and reimbursement rules for all parties if the agreements between providers, patients, payers and government regulators were agreed upon and stored via smart contracts on the blockchain. Providers would know accurately what type of information needed before submitting claims. Proper data format requirements stored on the blockchain would enable providers to format the claim data easily.
Fig. 4 Role of blockchain technology in the healthcare sector.
To ensure that, he should enter all information correctly. This clarity reduces or eliminates claims being returned due to insufficient data. It saves time and effort for all parties involved.

9 Blockchain: Fight against COVID-19 in healthcare

During the 2020–2021 period, the pandemic has affected people’s life drastically. It has upended how we lead our lives, conduct business, study, train, and play while cruelly snuffing our lives. Governments across the world are addressing these problems and urging their populations to stay safe and get vaccinated. BCT is an essential part of this fight to defeat the enemy. It helps establish an efficient and transparent healthcare business model based on higher degrees of accuracy and trust because technology is a tamper-proof public ledger. It cannot prevent the emergence of new viruses itself, but it can create the first line of protection through a network of connected devices whose primary goal is to remain alert about disease outbreaks. It can help prevent future pandemics by enabling the early spotting of epidemics, fast-tracking drug trials, and better management of outbreaks and subsequent treatment (Sharma, 2021b).

This technology helps share real-time information of all transactions between relevant parties in the chain in a secure and immutable fashion. If there been a blockchain with WHO, the Health Ministry of each country and nodal hospitals, the world might have woken up much earlier. We might have seen travel restrictions given sooner, quarantining policies set more shortly, and social distancing implemented faster. And fewer people would have suffered (Banafa, 2020). What every country is doing now fighting this pandemic would have been restricted to fewer countries on a smaller scale.

The following points explain how BCT could have been used to help in stemming the disease:

(a) Control disease:

BC can record patients’ symptoms and recovery due to the virus (Sharma et al., 2020). Even after the patient recovers, the data stored permanently in the blockchain help to check for after effects. Some patients do not get hospitalized but are isolated and treated at home. BCT facilitates to serve better home-quarantined patients by supplying medicine on time. Also, the data stored in the blockchain can be accessed by drug suppliers, medical stores, and doctors so that the patient will get adequate consultation on time.
(b) *Trace patients and areas:*

Blockchain can trace the contacts of those affected by the disease so that the people contacted can be examined. It can also locate the geographic area, safe zones, infected zones, etc. (Sharma et al., 2020).

(c) *Maintain and ramp up medical supply chains:*

The main challenges running around governments and corporates in a peak COVID pandemic around the globe is to get back the economy to normal. Mainly, the healthcare industry and its supply chain process must be revisited, and it is an immediate requirement to deal with a range of issues and challenges during pandemic times. Legacy procurement system in the medical supply chain breakdown the trust among customers and the public at large. Transforming the medical supply chain to the BCT based solves many problems. Product and manufactures details entered in the block is immutable and irreversible.

The decentralized distributed ledger system in BCT facilitates the parties involved in the supply chain process to get accurate real-time information. The merchant can receive standard medical equipment and track the origin. Companies like IBM and Microsoft are providing solutions for the medical supply chain through BCT. It is essential to supply medicines, medical equipment, ambulances, personnel, and accessories to the designated areas on time during catastrophic events. As blockchain can maintain a current database of designated personnel and equipment in real-time, it can help streamline resource distribution and aid in getting resources in time to those in need (GlobalData Healthcare, 2021; Sharma et al., 2020).

(d) *Make the treatment transparent:*

As the vaccination movement gathers steam, there are many rumors and incorrect reports on the same side effects. Blockchain can help find out where the “fake news” originated and help to curb the same. This will ensure that more and more people get vaccinated and hence help in eradicating the disease.

(e) *Track donations:*

As the world grapples with the pandemic and people lose livelihoods, many organizations have looked at helping those in need by collecting donations in money, food, books, medical supplies, etc. Blockchain specialists said that BCT could help track donations and make sure there is no misuse of funds or equipment (Aarvik, 2020; Banafa, 2020). It uses to check that essential goods are not overpriced or are not counterfeit goods. As it adds blocks from origin to end, goods
that start from a point cannot be changed en route. If they are changed, the point at which counterfeit goods are substituted will become clear. In India, various business houses like Amazon, Google, cricket team Royal Challengers, Bangalore, Mahindra etc., have pledged help to victims of COVID-19 (India.com, 2021; PTI, 2021; The Economic Times, 2021). While some companies are helping the families of employees who have suffered from the disease, others support the frontline workers. Governments disburse funds using the direct benefit transfer based on the Aadhaar card, a unique citizen id provided in India (The Economic Times, 2020). BCT will help in making sure that the allotted amount reaches the beneficiary.

(f) **Better Management:**

Most countries have been woefully unprepared for a crisis of this magnitude, which has led to the suffering of a kind never seen before. A shared platform like blockchain would enable early sharing of disease outbreaks with the World Health Organization and major healthcare agencies worldwide (Sharma et al., 2020). It could offer a platform where all concerned authorities, such as governments, health organizations, medical professionals, patients, NGOs, researchers and other connected individuals, can update each other about the situation and prevent it from worsening further.

(g) **Ease of claim process:**

BC enables the claim process and settlement easy. Agreements between patients, hospitals, medical suppliers, insurance companies, and governments are stored via ‘smart contracts in blockchain. The provider is aware of precisely the information required for submitting a claim application. BC maintains a proper data format, and it ensures all data entered correctly. BC removes errors in the conventional system. It minimizes and eliminates claims being returned due to insufficient information.

**Blockchain use cases:** BCT is a well suitable emerging technology for safeguarding every step of the healthcare supply chain. And various use cases for BC in the healthcare supply chain have already arisen, including advancing the efficiency of the IoHT (Internet of Healthy Things), securing internet-connected medical equipment, preventing fake pharmaceuticals, and more. Fig. 5 explains few COVID-19–related use cases for blockchain in healthcare.

There is an emerging need to strengthen the privacy, security, and trust of the developing digital environment specifically for the healthcare industry
Fig. 5 Some BCT based use cases for fighting the COVID-19 pandemic.
by using BCT, allowing public and mental health experts to proactively monitor treatments, independent of the patients’ or healthcare providers’ physical location. BC not only improves data consistency and accessibility across different cadres of healthcare providers and social services, but it also uses tokens and digital assets to incentivize healthy behavior. Globally, many companies and network agencies are providing healthcare services using BCT. Table 2 provides the details of few notable companies and their operations in the healthcare sector using BCT.

The most significant benefits offered by BC are associated with greater trust and privacy due to the technology’s ability to enable better data accuracy and verification. At its most basic level, blockchain changes ownership and control of data from one centralized source to multiple sources that contribute data (Furst, 2020).

10 Blockchain: Future in healthcare

Healthcare institutions are having problems integrating data at various points, such as maintaining a master database of all records, establishing trust, low costs to keep data, etc. BCT overcomes these problems by maintaining trust between the different stakeholders, lowering costs, and maintaining a trial for whoever has access to the records (Krawiec et al., 2016). The chapter already touched upon the beneficial impact new technologies have on the healthcare sector. When it comes to blockchain, the technology can impact the industry on a fundamental level. It could help build the digital infrastructure of a global healthcare system equipped to address today’s issues and confidently face the challenges of tomorrow. It could help ensure fair treatment of patients, efficient medical research, and cost-effective business operations (Kassab et al., 2019; Ribitzky, 2018; Siyal et al., 2019). The possibilities are truly limitless. Some of the far-reaching future uses of BCT in healthcare are:

(i) Managing and maintaining patients’ health records: The database can store all kinds of data, whether on blood pressure, cardiac care, height, weight and age, the amount spent in various consultations, insurance premiums etc. It will bring together data from online and offline consultations, apps, prescriptions used etc. This will make it easier for doctors to understand the patient’s background and previous treatments and prescribe customized treatments. The doctor will not need to spend time asking the patient to remember historical data, and even if the patient forgets essential information, it will not matter. With
its layers of protection and public and private keys, BCT will keep the data safely for the patient.

(ii) Settling Insurance Claims: Unfortunately, there are fraudulent claims made for health insurance companies. BCT can give a complete account of a health insurance petitioner’s sickness and subsequent bills. Hence, it will be impossible to fraud a health insurance company.

(iii) Managing the supply chain: Although most governments worldwide have regulations to regulate and protect the integrity of the supply chain, counterfeit drugs make their way into markets. These drugs are harmful to the public and can cause allergies or severe health issues for those taking them. Applying a blockchain to regulate the movement of the drugs from the manufacturer to the end-user will make it easy to pinpoint the node at which a fake drug substituted the actual drug. It will help in arresting the distribution of counterfeit medicines. Another application is to track the drugs’ real-time movement to know an accurate “Time of Arrival.”

(iv) Research and Development in Pharmaceuticals: The pace of research in the pharmaceuticals industry is phenomenal. Companies are racing against time to find cures to the novel Coronavirus along with other diseases. Whenever any breakthrough is arrived at, it is published in newspapers etc. However, during the research process to come to a breakthrough, there is no sharing of data or research. Here, BC facilitates sharing new drugs, thus making it faster to achieve a cure as companies can share their progress. Also, BC helps to publish medical research so that confirmation received for every research work’s validity. Another application of the BC is in the formulation of the drug. Every drug has the formula to be produced. BCT can evaluate, monitor and ensure that the drugs are being manufactured exactly as mapped in the procedure.

(v) Maintaining digital credentials of medical personnel: There is a vast amount of research on various topics in the medical community, especially regarding COVID-19. These research works will not be covered in medical education right away, but doctors will need to know about it. The research output can be disseminated through MOOCs, and healthcare professions can get trained in these and get a digital certificate stored using BCT. Also, storage of traditional degrees can be done using BCT, and as soon as there is an addition to the degree, it can be updated in the database, and all those who have access can view the updated data.
Clinical Research: Clinical Research is an essential part of knowing how effective new drugs are. However, they are difficult to conduct as there are data privacy issues, data integrity, data sharing, record keeping and patient enrolling. It has been proved that using blockchains makes the whole process transparent, makes transactions faster and leads to the faster enrolment of patients for clinical trials. This leads to quicker drug development.

11 Conclusion and recommendations

In today’s world, if we compare a transaction made through a bank and a BC, the transaction made through BCT is faster, cheaper and more secure. While the banking and finance world have looked at this technology keenly and have started utilizing it over the past few years, the healthcare industry has just begun evincing interest in this technology. While BCT has the power to revolutionize the way information about supply chains and patient’s health records can be stored and retrieved, very few companies have utilized this. With this technology, healthcare providers can maintain medical records confidentially, update them whenever necessary across numerous facilities and locations in real-time and with security. In today’s time, where the healthcare infrastructure is stretched, this would be very useful as it would reduce time in administration and enable redirection toward patient care.

India’s public think tank government, called the “Niti Aayog,” has carried out pilot studies on BCT use for various projects such as maintaining land records, issuing educational certificates, etc. (Aayog, 2020). This document has explored BC application in two essential healthcare areas: Medical supply chains and the other is the immunization program. The report details out how BCT can streamline and improve the current methods of delivering medicines and vaccinations. The group conducted a pilot study to trace the supply chain of medication from origin to endpoint. The reason was due to combat the entry of counterfeit drugs anywhere during the entire process. The group collaborated with manufacturer, logistics vendors and hospitals. They realized that BCT could vastly improve transparency, efficiency and reliability of the supply of drugs. The second use that the report cites is to use the technology to create a new immunization system enhanced by BCT that would reach all children in India. BCT would help by keeping records of the cold chain supply of the vaccines. It helps to keep a record of births so that vaccination can happen at the right age. It creates an alert
system so that parents know when the vaccination is due, and these can be encouraged through incentives to parents and healthcare workers to vaccinate children. Another payoff was that it could help the government to track all its schemes. These payoffs would lead to a healthier and thus wealthier society for a developing country like India.

As with all other technologies, BCT also has a few drawbacks. While they are not insurmountable, it is best to be aware of them before incorporating this technology. The disadvantage of this technology is that adoption and implementation are expensive as it consumes enormous power. However, newer forms of technology are coming forward so that more organizations can make use of it. The security layer that “proof of work” provides consumes a lot of energy and computing power. Newer versions of BCT employ “proof of stake” and “proof of burn,” which are less expensive. Also, this technology was designed to store transactions. As its use gets more widespread, it will keep more data, so storage capacity will need to be increased, and as more transactions and more data will be recorded and stored, there will be a need to speed the transactions. BCT will need to be scalable and more resilient.

To practically implement the BCT in healthcare, international standardization authorities will need to be involved to set standards. These standards for technology and healthcare would be helpful to evaluate the size, type of data, and format of the information in the database. This chapter has listed the benefits of BCT as a technology that has immense benefits as it is decentralized, immutable, secure, and auditable. The chances of committing fraud are meager. In the long run, this technology will be cheaper and faster to run and maintain. Like any technology that comes in, setting up will require companies to change mindsets and train people. However, that is a small cost to pay for the immense benefits that BCT brings, and they can save costs.

While adoption by healthcare companies has been slow, there have been some use cases to showcase BCT use in healthcare. By examining more than 20 companies that have incorporated this technology, it is clear that the time for BCT is here and now. As companies look forward to reaching customers faster and increasing efficiencies, BC will become even more essential. The COVID-19-induced pandemic has shown to us that we need healthcare systems that are robust and that can move fast, reach the patient quicker and alleviate suffering. At this juncture in our history, we need to be exceptionally responsive to social needs and BC, Artificial intelligence, the Internet of Healthy Things (IoHT), and plain common sense can help there.
References

Aarvik, P., 2020. Blockchain Technology to Prevent Corruption in Covid-19 Response: How Can it Help Overcome Risks? CMI Chr. Michelsen Institute. https://www.cmi.no/publications/7259-blockchain-technology-to-prevent-corruption-in-covid-19-response-how-can-it-help-overcome-risks. (Accessed 1 June 2021).

Aayog, N.I.T.I., 2020. Blockchain: The India Strategy. http://niti.gov.in/sites/default/files/2020-01/Blockchain_The_India_Strategy_Part_I.pdf. (Accessed 10 April 2021).

Ali, O., Jaradat, A., Kulakli, A., Abuhalimeh, A., 2021. A comparative study: blockchain technology utilization benefits, challenges and functionalities. IEEE Access 9, 12730–12749. https://doi.org/10.1109/ACCESS.2021.3050241.

Arsene, C., 2020. The Global “Blockchain in Healthcare” Report: The 2021 Ultimate Guide for every Executive. healthcareweekly.com. https://healthcareweekly.com/blockchain-in-healthcare-guide/. (Accessed 14 December 2020).

Banafa, A., 2020. Blockchain Technology and COVID-19. Open Mind. https://www.bbvaopenmind.com/en/technology/digital-world/blockchain-technology-and-covid-19/. (Accessed 1 June 2021).

Chakraborty, P., 2021. The Growing World of NFT. The Times of India. https://epaper.timesgroup.com/Olive/ODN/TimeOfIndia/shared/ShowArticle.aspx?doc=TOIM%2F2021%2F05%2F20&entity=Ar00502&sk=2C5FF52B&mode=text#. (Accessed 30 May 2021).

Combs, V., 2021. 177% increase_ Hackers grabbed 21.3 million healthcare records in the second half of 2020. Tech Republic. https://www.techrepublic.com/article/177-increase-hackers-grabbed-21-3-million-healthcare-records-in-the-second-half-of-2020/. (Accessed 26 May 2021).

Daley, S., 2021. How using blockchain in healthcare is reviving the industry’s capabilities. builtin.com. https://builtin.com/blockchain/blockchain-healthcare-applications-companies. (Accessed 28 May 2021).

Davis, J., 2020. Update: The 10 Biggest Healthcare Data Breaches of 2020. Xtelligent Healthcare Media. https://healthitsecurity.com/news/the-10-biggest-healthcare-data-breaches-of-2020. (Accessed 26 May 2021).

EUBlockchain, 2021. EU blockchain ecosystem developments. The European Union Blockchain Observatory & Forum, pp. 1–200. https://www.eublockchainforum.eu/sites/default/files/reports/EU%20Blockchain%20Ecosystem%20Report_final_0.pdf. (Accessed 13 June 2021).

Fauci, A.S., Lane, H.C., Redfield, R.R., 2020. Covid-19-navigating the uncharted. N. Engl. J. Med. 382 (13), 1268–1269. https://doi.org/10.1056/nejme2002387.

Frankenfield, J., 2021. Proof of Work (PoW) Definition. Investopedia. https://www.investopedia.com/terms/p/proof-work.asp. (Accessed 2 June 2021).

Furst, B., 2020. How COVID-19 Has Revealed Healthcare’s Blockchain Use Cases. hitconsultant.net. https://hitconsultant.net/2020/11/17/covid-19-healthcare-blockchain-use-cases/#YKJFqqqY2w. (Accessed 10 June 2021).

GlobalData Healthcare, 2021. Covid-19-induced digital transformation did prioritise blockchain.pdf. Pharmaceutical Technology. https://www.pharmaceuticaltechnology.com/comment/covid-19-induced-digital-transformation-did-prioritise-blockchain/. (Accessed 22 May 2021).

India.com, 2021. Google’s GiveIndia to Provide Cash Assistance to Families Hit Hardest by Covid-19 Crisis. Deets Here. https://www.india.com/technology/googles-giveindiatoprovide-cash-assistance-to-families-hit-hardest-by-covid-19-crisis-deets-here-4616106/. (Accessed 1 June 2021).

Iredale, G., 2020. List of Top 50 Companies Using Blockchain Technology. 101 blockchains. https://101blockchains.com/companies-using-blockchain-technology/. (Accessed 30 May 2021).
Kassab, M.H., DeFranco, J., Malas, T., Laplante, P., Destefanis, G., Graciano, N.V.V., 2019. Exploring research in blockchain for healthcare and a roadmap for the future. IEEE Trans. Emerg. Top. Comput. 1. https://doi.org/10.1109/TETC.2019.2936881.

Knowledge@Wharton, 2018. How the Blockchain Brings Social Benefits to Emerging Economies. Wharton University of Pennsylvania. 28 November https://knowledge.wharton.upenn.edu/article/blockchain-brings-social-benefits-emerging-economies/. (Accessed 24 July 2021).

Krawiec, R.J., Housman, D., White, M., Filipova, M., Querre, F., Barr, D., Nesbitt, A., Fedosova, K., Killmeyer, J., Israel, A., Tsai, L., 2016. Blockchain: Opportunities for Healthcare. https://www2.deloitte.com/us/en/pages/public-sector/articles/blockchain-opportunities-for-health-care.html. (Accessed 28 May 2020).

Kuner, C., Cate, F., Lynsky, O., Millard, C., Loideain, N.N., Svantesson, D., 2018. Blockchain versus data protection. Int. Data Privacy Law 8 (2), 103–104. https://academic.oup.com/idpl/article/8/2/103/5047578.

Lauren, D., Dent, M., Castillo, M.D., Hansen, S., Kaufin, J., Sorvino, C., Tucker, H., 2021. Blockchain 50. In: Castillo, M.D., Schifrin, M. (Eds.), Forbes. https://www.forbes.com/sites/michaeldelcastillo/2020/02/19/blockchain-50/?sh=77cf78b77553. (Accessed 30 May 2021).

Luu, L., Narayanan, V., Zheng, C., Bawecha, K., Gilbert, S., Saxena, P., 2016. A secure sharding protocol for open blockchains. In: Katzenbeisser, S., Weippl, E. (Eds.), Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security. CCS’16. 24–28 October 2016, Vienna, Austria. Association for Computing Machinery, New York, NY, USA, pp. 17–30. https://doi.org/10.1145/2976749.2978389.

Lyons, T.C.L., 2020. Blockchain Use Cases in Healthcare. Frankfurt. www.eublockchainforum.eu/sites/default/files/reports/report_healthcare_v1.0.pdf. (Accessed 20 September 2020).

Martindale, J.R., 2018. Merging developed and developing worlds: the blockchain revolution’s impact on collective global growth. New Visions Public Affairs 10, 39–47.

Mathew, A.R., 2019. Cyber security through blockchain technology. Int. J. Eng. Adv. Technol. 9 (1), 3821–3824. https://doi.org/10.35940/ijeat.A9836.109119.

Mishra, N.T.P., Das, S.S., Yadav, S., Khan, W., Afzal, M., Alarifi, A., Kenawy, E.-R., Ansari, M.T., Hasnain, M.S., Nayak, A.K., 2020. Global impacts of pre- and post-COVID-19 pandemic: focus on socio-economic consequences. Sens. Int. 1. https://doi.org/10.1016/j.sint.2020.100042, 100042.

MoF, 2021. Union Budget 2021. Government of India. https://www.indiabudget.gov.in/. (Accessed 28 May 2021).

Monttechi, M., Plangger, K., Etter, M., 2018. It’s real, trust me! Establishing supply chain provenance using blockchain. Business Horizons, 1–11. https://doi.org/10.1016/j.bushor.2019.01.008.

Nakamoto, S., 2009. Bitcoin: A Peer-to-Peer Electronic Cash System. https://www.bitcoinpaper.info/bitcoinpaper-html/. (Accessed 25 May 2021).

Oppili, P., 2021. Lioness dies of suspected coronavirus infection in Chennai’s Vandalur zoo; nine lions test positive. http://timesofindia.indiatimes.com/articleshow/83228324.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst. (Accessed 10 June 2021).

PTI, 2021. Amazon India launches COVID-19 financial support for eligible staff. https://www.businessdaytoday.in/current/corporate/amazon-india-launches-covid-19-financial-support-for-eligible-staff/story/4398881.html. (Accessed 1 June 2021).

PwC, 2018. PwC’s Global Blockchain Survey. https://www.pwc.com/gx/en/industries/technology/blockchain/blockchain-in-business.html. (Accessed 20 July 2021).

Ribizky, R., St. Clair, J., Houlding, D.I., McFarlane, C.T., Ahier, B., Gould, M., Flannery, H.L., Pupo, E., Clauson, K.A., 2018. Pragmatic, interdisciplinary perspectives on
Blockchain and distributed ledger technology: paving the future for healthcare. Blockchain in Healthcare Today, 1. https://doi.org/10.30953/bhty.v1.24.

Sahu, M., 2020. 8 Reasons Why Blockchain Technology Is The Future. UpGrad [Blog]. https://www.upgrad.com/blog/reasons-why-blockchain-technology-is-the-future/. (Accessed 1 June 2021).

Service, I. A. News, 2019. Hackers attack Indian healthcare website, steal 6.8 million records. DataBreaches.net. https://www.databreaches.net/hackers-attack-indian-healthcare-website-steal-68/. (Accessed 26 May 2021).

Sharma, A., Bahl, S., Bagha, A.K., Javaid, M., Shukla, D.K., Haleem, A., 2020. Blockchain technology and its applications to combat COVID-19 pandemic. Res. Biomed. Eng., 1–8. https://doi.org/10.1007/s42600-020-00106-3.

Sharma, M., 2021a. When is a Third Wave of Covid-19 likely to Hit India? Coronavirus Outbreak News. https://www.indiatoday.in/coronavirus-outbreak/story/india-third-wave-of-covid-19-vaccine-prevention-1799504-2021-05-06. (Accessed 2 June 2021).

Sharma, T.K., 2021b. How Blockchain Can Solve Major challenges of COVID-19 Faced by Healthcare Sectors? https://www.blockchain-council.org/blockchain/how-blockchain-can-solve-major-challenges-of-covid-19-faced-by-healthcare-sectors/. (Accessed 2 June 2021).

Singh, S., Hosen, A.S.M.S., Yoon, B., 2021. Blockchain security attacks, challenges, and solutions for the future distributed IoT network. IEEE Access 9, 13938–13959. https://doi.org/10.1109/ACCESS.2021.3051602.

Siyal, A.A., Junejo, A.Z., Zawish, M., Ahmed, K., Khalil, A., Soursou, G., 2019. Applications of blockchain technology in medicine and healthcare: challenges and future perspectives. Cryptography 3 (3), 2–16. https://doi.org/10.3390/cryptography3010003.

Tandon, A., Dhir, A., Islam, A.K.M.N., Mäntymäki, M., 2020. Blockchain in healthcare: a systematic literature review, synthesising framework and future research agenda. Comput. Ind. 122, 103290. https://www.sciencedirect.com/science/article/pii/S0166361520305248. https://doi.org/10.1016/j.compind.2020.103290.

The Economic Times, 2020. Direct benefit transfer: Covid-19: govt to transfer financial assistance only through DBT mechanism. April 16 https://economictimes.indiatimes.com/news/politics-and-nation/covid-19-govt-to-transfer-financial-assistance-only-through-dbt-mechanism/articleshow/75185835.cms?from=mdr. (Accessed 1 June 2021).

The Economic Times, 2021. COVID-19: RCB promises financial help for oxygen support, to also raise funds. The Economic Times. May 6 https://economictimes.indiatimes.com/news/india/covid-19-rcb-promises-financial-help-for-oxygen-support-to-also-raise-funds/articleshow/82351935.cms. (Accessed 1 June 2021).

TNN, 2021. PM Cares to pay for education, care of children orphaned by Covid-19. Times of India. https://timesofindia.indiatimes.com/india/government-to-support-kids-who-lose-parents-to-covid-19-via-pm-cares/articleshow/83065497.cms. (Accessed 30 May 2021).

Transparency International, 2020. Corruption Perceptions Index. https://www.transparency.org/en/cpi/2020/index/nzl. (Accessed 23 June 2021).

Ugalnugle, S., Swain, R., 2019. Blockchain Technology in Healthcare Market Size by Application. Global Market Insights. Report ID: GMI3098 https://www.gminsights.com/industry-analysis/blockchain-technology-in-healthcare-market. (Accessed 20 June 2021).

WHO, 2021a. Coronavirus disease (COVID-19) pandemic. https://www.who.int/emergencies/diseases/novel-coronavirus-2019. (Accessed 15 June 2021).

WHO, 2021b. COVID-19 weekly epidemiological update 22 December 2020. World Health Organization. pp. 1–3. https://www.who.int/publications/m/item/weekly-epidemiological-update—22-december-2020. (Accessed 12 February 2021).
Xu, J.J., 2016. Are blockchains immune to all malicious attacks? Financial Innovation 2 (25).
https://jfin-swufe.springeropen.com/articles/10.1186/s40854-016-0046-5#citeas.

Zago, M., 2018. 50+ Examples of How Blockchains are Taking Over the World. https://medium.com/@essential/50-examples-of-how-blockchains-are-taking-over-the-world-4276bf488a4b. (Accessed 31 May 2021).

Zambrano, R., 2020. Taming the beast: harnessing blockchains in developing country governments. Front. Blockchain 2, 27. https://www.frontiersin.org/article/10.3389/fbloc.2019.00027. (Accessed 31 May 2021).

Zheng, Z., Shaoan, X., Hongning, D., Xiangping, C.H.W., 2018. Blockchain challenges and opportunities: a survey. Int. J. Web Grid Services 14 (4), 352–375. https://doi.org/10.1504/IJWGS.2018.10016848.