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# A Review: Future of Healthcare Industry with Blockchain Technology

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**ABSTRACT**

Healthcare and Pharmaceutical sectors are the data-intensive clinical domains where a huge amount of data is generated, accessed, and disseminated regularly. The major problems faced by the healthcare sector include fragmented data across several silos negatively affecting research and services, about half of the clinical trials never being reported, a constant increase in the cost of drug discovery, substandard and fake medicines. Blockchain has the potential to solve these problems as it provides trust without any intermediaries, has traceability as a default feature, and promises new business models by enabling novel incentive structures. Due to its potential, blockchain has gathered significant interest in the healthcare industry. In this paper, we review major use cases of blockchain in healthcare: patient data management, pharmaceutical research, supply chain management of medical goods, prescription management, billing claims management, neuroscience, clinical research, and telemedicine alongside the related projects. We also threw light on the key challenges faced in their implementation.

## 1. INTRODUCTION

The quality management system in pharmaceuticals helps to improve the product quality and minimize the risk of product recall [1]. Discovery of any new product into the pharmaceutical industry is difficult for drug development and approval by regulatory bodies. When all the process is done and a standard product is developed, the next challenge for manufacturers is to deliver the product to the customer in its original form and to ensure that the customer gets the genuine product that is developed by the legitimate manufacturer, not by counterfeiter [2]. In the last 20 years, product recall has increased due to loopholes at various stages of manufacturing procedure that ultimately leads to compromised quality of product and mismanaged supply chain management. According to World Health Organization (WHO) in 1992, counterfeiter defines as (world Latin counterfeits meaning to imitate) "Counterfeit medicine is one which is deliberately mislabelled concerning genuine drug into their own identity, composition, and source of that drug. Counterfeit products may include products with the correct ingredients or with the wrong ingredients, without active ingredients or with insufficient active ingredients or with fake packaging"[3]. Different Categories of Counterfeit Drugs are shown in figure 1.

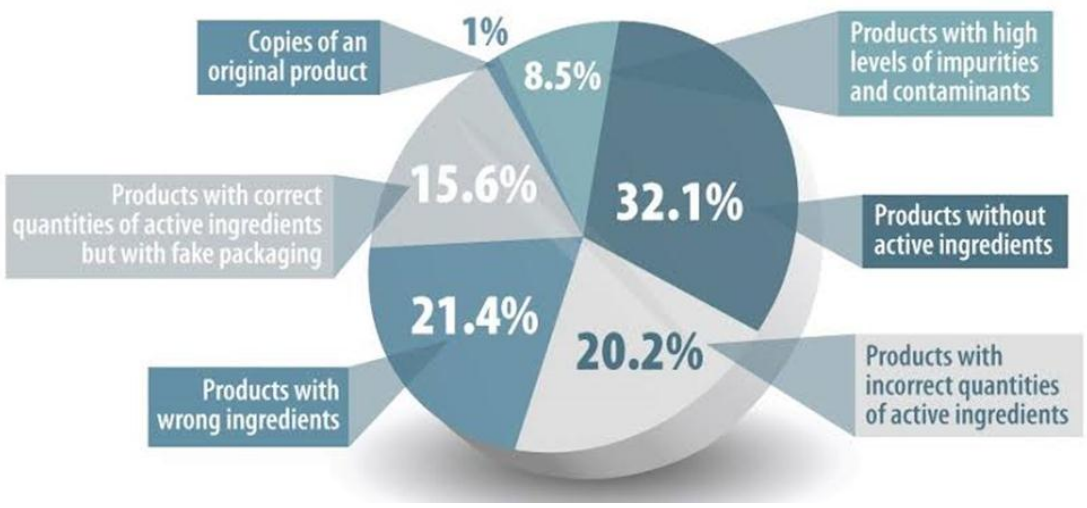


**Figure No. 1: Different Categories of Counterfeit Drugs [4]**

The World Health Organization [WHO] has estimated 1 in 10 drugs in market circulation are falsified or substandard [5]. These products also affect the economy. The world does not have accurate basic statistics, such as the number of substandard drugs. However, for the past few years, public opinion and experts have passively accepted the argument that 10% of

medicines around the world could be counterfeit the consequences of this phenomenon pose significant risks to individuals and the public [6].

The contribution of counterfeit products as a leading cause of deaths has significantly increased so much so that more than 1 million patients have died in the last 10 years. Some statistics related to death due to counterfeits drugs are shown in figure 2. Counterfeiting drugs are most commonly observed in pharmaceutical products that are used to treat severe diseases like cancer, tuberculosis, influenza, malaria, etc.

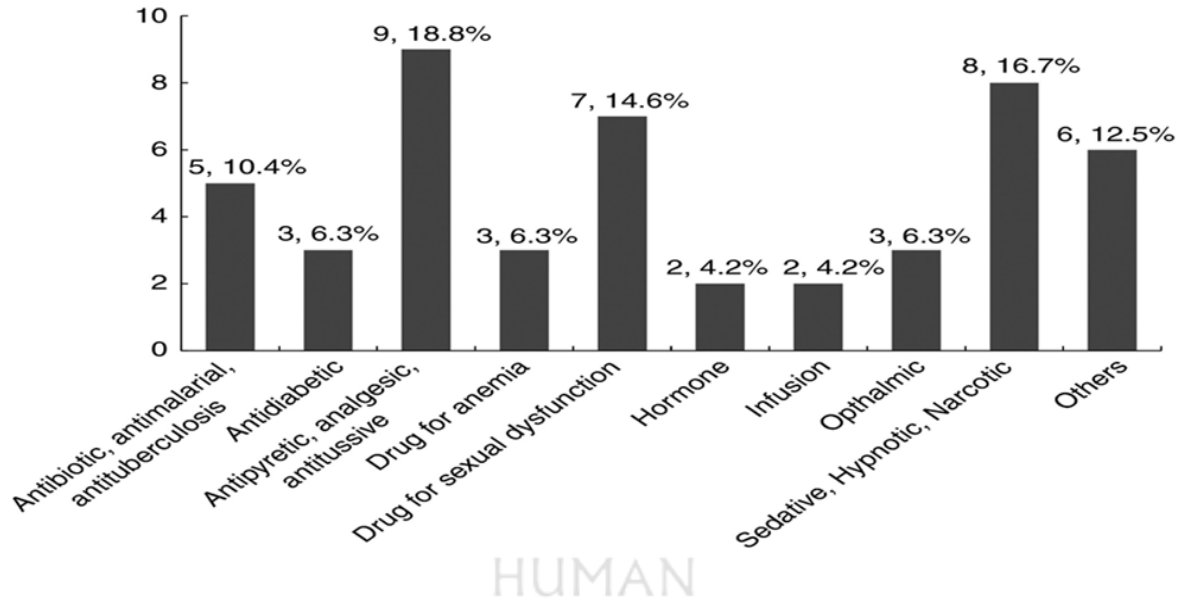


**Figure No. 2: Deaths due to Counterfeit Drugs [7]**

To control or to minimize the risk of substandard or counterfeiter US has implemented the Drug Supply Chain Security Act (DSCSA). The Act has been implemented amongst other things to fight the counterfeit drug problem. The supply chain in the pharmaceutical industry is complex with drugs changing ownership from manufacturers to distributors, repackages, and wholesalers before reaching the customer. There is little to no visibility for manufacturers throughout the supply chain to track authenticity. Consequences include the counterfeit drug problem and inefficient processes for conducting recalls and returns processing. These inefficiencies result in financial losses and loss of trust with consumers. The blockchain could be an opportunity platform to increase trust and transparency, with customers being able to track pharmaceutical products throughout the supply chain [8]. This technology was introduced by pseudonym Satoshi Nakamoto in 2008[9]. ‘Blockchain technology is a distributed electronic ledger of digital records, events or transactions that are cryptographically

secure, extremely hard to forge, and updateable through a consensus protocol agreeable to all connected nodes'.

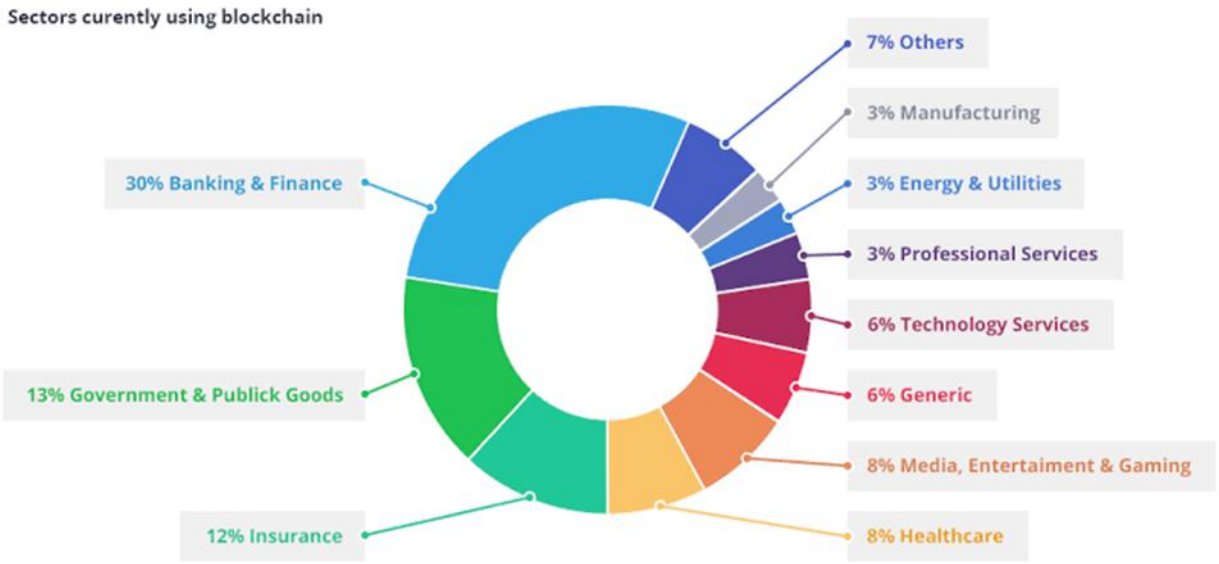


**Figure No. 3: Blockchain Technology in Various Sectors [10]**

### 1.1 Blockchain Technology:-

Historically, Blockchain is known to be the technology powering Bitcoin, as an open distributed public ledger, recording all the Bitcoin transactions in a secure and verifiable way without the need for a third party to process payments. In this context, Blockchain can be considered a full history of banking transactions. More generically, Blockchain is a huge, public, secure and decentralized datastore of ordered records, or events, called blocks. Each block contains a timestamp and is linked to a previous block. Events can be updated by only a majority of users. Information cannot be erased. The data store is owned by no one, is controlled by users, and is not ruled by any trusted third party or central regulatory instance. [11].The technology uses decentralized consensus algorithms to control database consistency[12]. This technology is robust and effective [13]. A Blockchain technology follows a P2P network. It is a peer-to-peer integrated multi-field network framework, composed of cryptography, algorithms, and mathematical expressions aimed at solving traditional distributed database synchronization limitations by using distributed consensus algorithms.

The Blockchain technology principally contains six key elements: Decentralized, transparent, immutable, autonomy, open-source, and anonymity described in Table-1.

**Table No. 1: Key Elements of Blockchain Technology [14]**

| Key Elements | Functional Description |
|---|---|
| Decentralized | A database system with open access control to anyone connected to the network. The data can be accessed, monitored, stored, and updated on multiple systems. |
| Transparent | The recorded and stored data on the blockchain is transparent to potential users, which can be further updated easily. The transparent nature of blockchains could certainly prevent data from being altered or stolen. |
| Immutable | The records, once stored, become reserved forever and cannot be modified easily without having control of more than 51% of the node concurrently |
| Autonomy | The blockchain system is independent and autonomous, meaning that each node on the blockchain system can access, transfer, store, and update the data safely, making it trustworthy and free from any external intervention |
| Open Source | The blockchain technology is formulated in a way that provides open source access to everyone connected to the network. This inimitable versatility entitles anyone, not only to check the records publicly but also develop various impending applications |
| Anonymity | As data transfer occurs between node to node, the identity of the individual Remains anonymous, thus making it a more secure and reliable system. |

Blockchain technology depends upon three phases to improve the security of particular information i.e 1) Data 2) Hash 3) Hash of Previous Block (HOPB). This three-phase are connected by the security key. The working principle of blockchain is shown in figure 4.

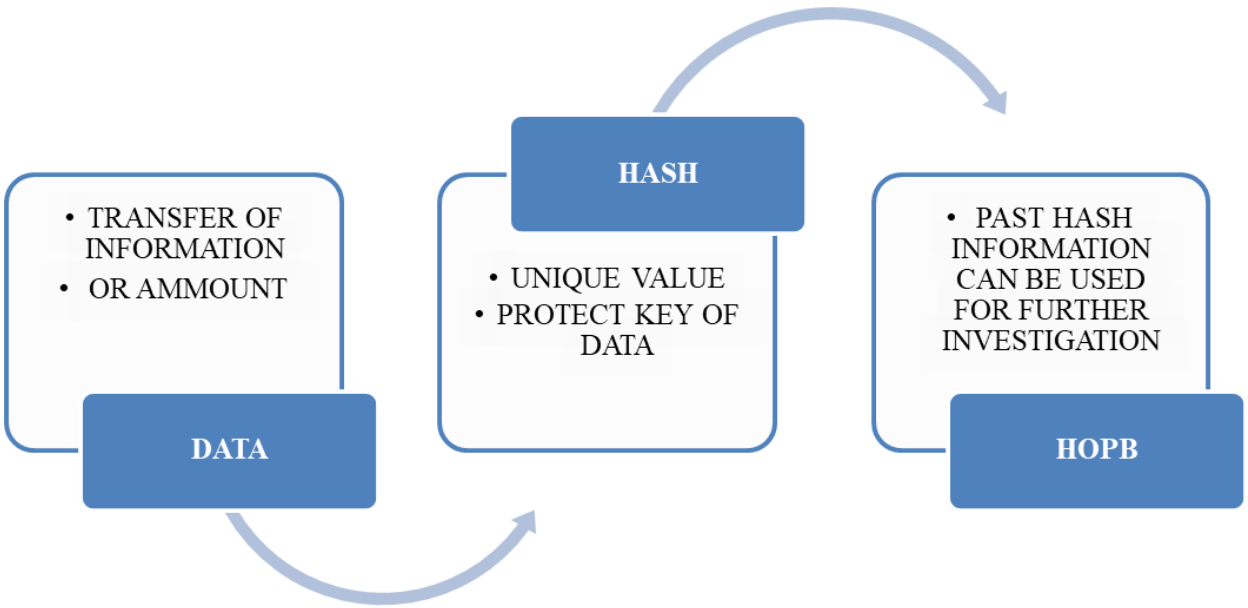


**Figure No. 4: Working Principles of Blockchain Technology**

Another reason to implement Blockchain technology is that it can address three dimensions i.e address collaboration, cost optimization, and risk management. This technology allows companies to gain total access to the end-to-end supply chain data while ensuring that it can be securely stored and privately shared with authorized stakeholders. As a decentralized shared ledger that requires cryptographic signatures for access and modification, the block-chain technology can create a transparent, traceable system of recording transactions across the product life cycle [13].

**1.2 Types of Blockchain Technology**:-

Blockchain technology is classified based on three types of concepts that are: 1) based on data accessibility, 2) based on authorization to participate, and 3) based on core functionality and smart contract. Details are shown in Table 2, Table 3, and Table 4 respectively.

**Table No. 2: Types of Blockchain Technology Based on Data Accessibility [15]**

| **Public blockchain technology** | **Private Blockchain Technology** | **Community/Consortium blockchain technology** | **Hybrid Blockchain Technology** |
|---|---|---|---|
| **Public blockchain technology is open to all, anyone one can read and submit transactions** | Private Blockchain technology can be used by only one organization or all subsidiary organizations within the same group are allowed to read and submit transactions. | Consortium blockchain technology is a hybrid of public and private blockchain technology but it includes more components of private/ has more features similar to the private blockchain technology | This is a new categorized concept where any of three Public, Private, or Community/Consortium, Blockchain technology can be combined to facilitate or to secure transactions. A Blockchain platform can be configured/ secure in multi-mode using Hybrid Blockchain technology |

**Table No. 3: Types of blockchain Technology Based on Authorization [15]**

| **Permission Less blockchain technology** | **Permissioned blockchain technology** |
|---|---|
| **No prior permission is required to participate in this type of Blockchain technology everyone is allowed to participate in the verification process and can join the Blockchain technology network with their computational power. EgBitCoin, Etherum** | To join this type of Blockchain technology prior permission is needed. Only authorized parties are allowed to run nodes to verify transactions in the Blockchain technology network. |

**Table No. 4: Types of blockchain Technology Based On Core Functionality and Smart Contracts[15]**

| Stateless blockchain technology | Stately blockchain technology |
|---|---|
| **Stateless Blockchain technology systems only focus on transaction optimization and chain functionality that is verifying the transaction by computing hashes. It is independent of the smart contract logic layer thus unaffected from smart contract code bugs and vulnerabilities.** | This type of Blockchain technology provides smart contract and transaction computing capabilities. It also supports multifaceted business logic, its optimization, and preserves logic states. |

**1.3 Functioning of Blockchain Systems-Consensus Mechanisms:-**

The consensus is nothing but the type of algorithms which are used for proper implementation of blockchain technology for specific transaction/work [16]. The consensus in a blockchain network is the mechanism on agreeing on a common version or state of the blockchain which is considered to be the trusted truth of the blockchain. A consensus protocol includes the rules for transaction validation, accepting the newly created block into the chain, and selection of fork/partition in case of network partitions. Depending on the context and the use case, the need and requirement for the consensus could differ. The consensus mechanism can be broadly classified as global or local. In the global consensus model, the first block of the chain called genesis block is common for all nodes in the network and every node agrees on the same state of the network and stores the complete chain to validate any transaction. The most common examples of global consensus blockchain are Bitcoin and Ethereum. In the local consensus model, every participant owns an individual genesis block and the consensus is only reached among the parties involved in the transactions. This local consensus reduces the storage requirements on individual nodes and is generally more scalable than global consensus counterparts. Example blockchains are TrustChain and Nano[17].

**1.4 Block Validation Model:-**

There are two types of block validation model used by consensus. Global consensus uses proof of work (PoW) for accepting the new block and dictates to choose the longest chain in case of network partitions. In PoW, miners compete to find a cryptographic hash that solves a computationally difficult problem, and the block proposed by the miner with the correct hash is added to the chain. Proof of work is resource-intensive and inherently non-scalable. Proof

of stake (PoS) is an alternative block validation model where the creator of the new block is chosen in a deterministic way depending on its wealth, also called the stake. PoS is much more efficient in terms of performance and energy consumption. We are observing a shift from PoW to PoS or hybrid model in recent blockchains where Ethereum remains a strong proponent[17][18].

**1.5 Smart Contracts:-**

A smart contract represents a self-executing, self-verifying, and tamper-resistant piece of code with programmable application logic that resides and executes on the blockchain. It formalizes the transaction rules and relationships among entities and assets in the blockchain and gives the flexibility to write custom application logic which becomes a law enforced by the blockchain itself without any reliance on trusted intermediaries. Smart contracts form the basis for trust in the application layer [17][19].

## 2. Application of Blockchain Technology in Medicine and Health Care System:-

Blockchain technology was originally implemented in banking and finance applications in the form of cryptocurrencies, but over time its potential has expended in various domains including healthcare and biomedical field. The potential of blockchain technology can be witnessed in the fields of medicine, genomics, e-health, neuroscience, and personalized healthcare applications. Blockchain technology provides a stable and secure mechanism to store and share data in all sub-domains of the healthcare industry, so that stored data can be used for different types of transactions and experiments by physicians and healthcare providers. The application of blockchain technology is discussed below[20]. Figure 5 shows the application of blockchain technology in the healthcare industry.

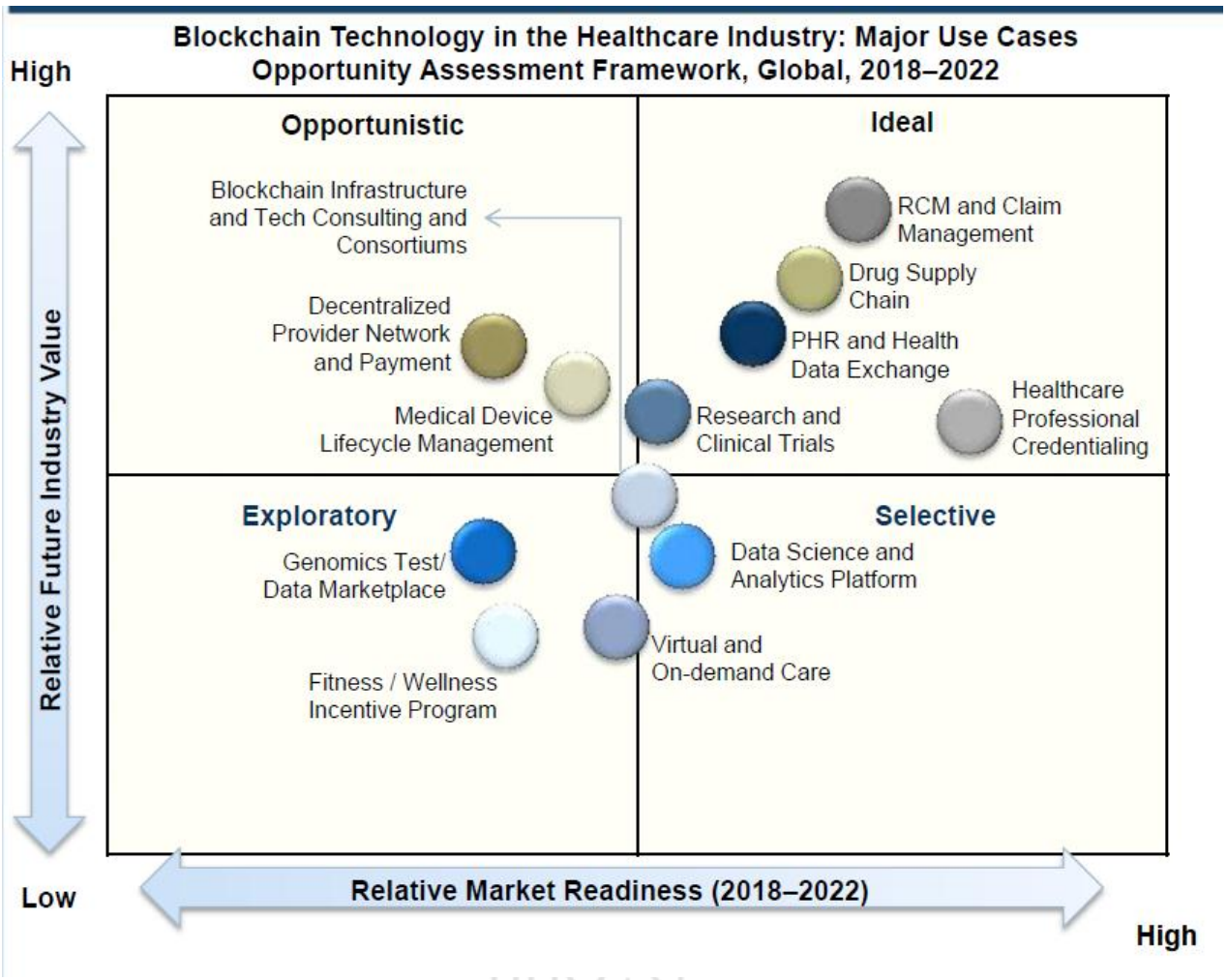


**Figure No. 5: Blockchain Technology Application in Healthcare Industry [21]**

### 2.1 Blockchain Technology in Electronic Health Records (EHR):

Patient's data were scattered among various healthcare providers according to the situation of patients and the past data was not accessible even in EHR systems. The requirement of medical practitioners and healthcare providers of easy access to the available information of patients that would enable them to make quick decisions in emergencies with full precautions led to the increased adaptation of digitization in the healthcare system. Electronic health records (EHR) are the digital version of data and these records are available at any time with enhanced security to authorized healthcare providers. Electronic health records contain a patient's medical history, diagnosis reports, medication, and treatment plans, etc. This is the most common application of blockchain technology in the healthcare system that makes data more secure with limited authorized access, thus reducing the chances of forgery and misuse of medical data for any illegal purposes [20].

A prototype named “MedRec” utilizes distinct blockchain perks in managing authentication, confidentiality, integrity, and easy sharing of data. It works on a decentralized records management system and claims to provide patients a detailed, immutable history and allows easy access to their respective healthcare information across various providers and treatment institutions. “MedRec” doesn’t store medical records or require an adjustment time. It stores a mark of the record on a blockchain and advises the patient, who is eventually responsible for where that record can move. The mark guarantees that an unchanged duplicate of the record was acquired. It likewise moves the power of control from the organization to the patient and consequently this both weights and empowers the patient to assume the responsibility of the owner [14].

**2.2 Blockchain technology in Clinical Research:-**

Clinical research deals with studies of a new molecular entity or drug being tested at the clinical level. Clinical trials are one of the aspects of clinical research where any new drug molecule having therapeutic action against particular ailment or disease is analyzed for various parameters like drug distribution, bioavailability, therapeutic effect, adverse effects, and others in the human body. Since clinical trials directly involve humans, it only commences after the new drug entity is proven safe and effective on animals in preclinical studies. The drug undergoes 4 clinical phases that are designed in a categorical manner setting different priorities at each phase as follows: Phase I studies aim at assessing the safety of a drug. Phase II studies test the efficacy of a drug. Phase IIIstudies involve randomized and blind testing in several hundred to several thousand patients. Phase IV studies deal with Post Marketing Surveillance Trial[22]. Detailed application of blockchain technology at each level of drug development is explained in [Figure: 6] whereas companies that are currently involving blockchain technology are shown in Table 5.

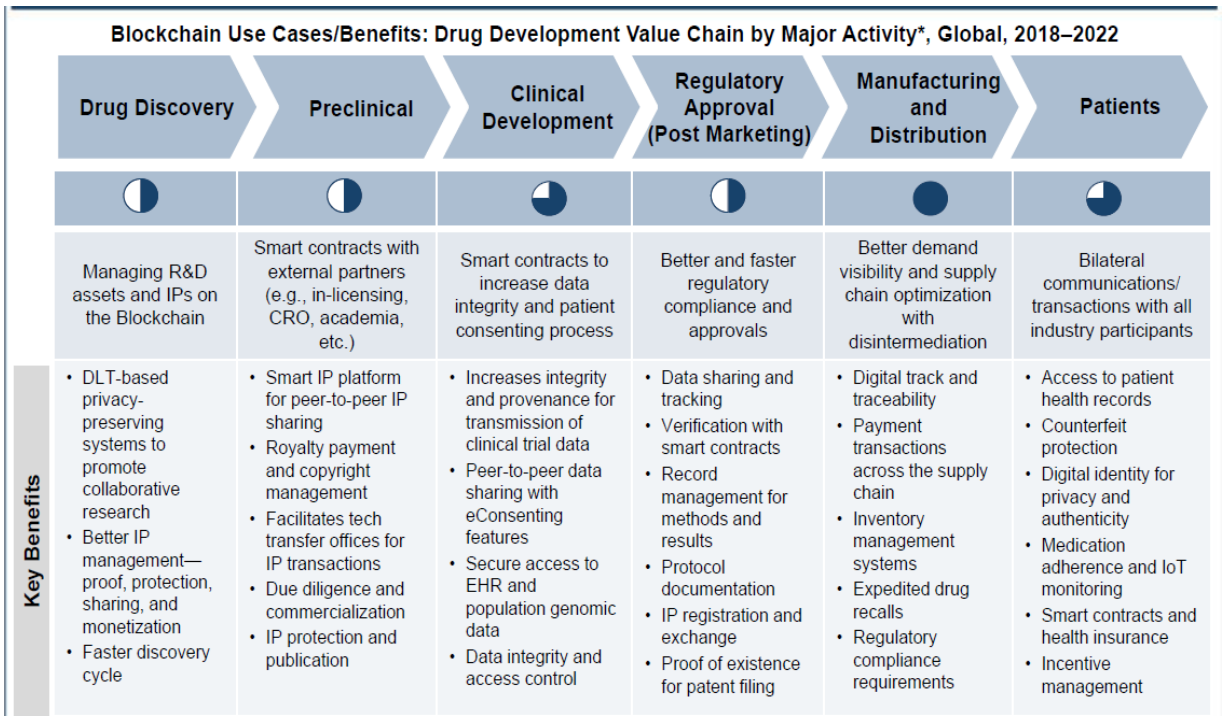


**Figure No. 6: Blockchain Technology in Drug Development Chain [21]**

**Table No. 5: Companies and Initiatives That Use/Plan to Use Blockchain-Based Solution for Clinical Trials [21]**

| Company | Use case | Product | Application |
|---|---|---|---|
| ConsilX | Clinical Trial eConsenting, eSource/Data notarization, Supplies Tracking | LifeLedger | LifeLedger™ v1.0 is a patient-centered platform that offers integrated consent management and patient engagement through real-time interaction and clinical supplies tracking in a single application.<br>The platform leverages on a cohort of technologies with Blockchain as the backbone for automatic and secured data aggregation to improve interoperability and research collaboration, resulting in enhanced efficiency and compliance across the clinical trial process. The platform also uses an AI-based algorithm and identifies potential patients based on inclusion/exclusion criteria.<br>Future plans include the creation of a Blockchain-based community for collaboration and selective data sharing across pharma for faster clinical development and<br>commercialization of future drugs |
| Medable | Clinical Trial data sharing for RWE | INSIGT Network | In March 2018, Medable announced the INSIGHT Network, a Blockchain-powered platform that enables auditable, transparent medical data exchange, and aligns incentives among patients, |

| | | | |
|---|---|---|---|
| | | | medical researchers, and biopharmaceutical companies for self-directed RWE data sharing.<br>With more than 15 million patients data and over 6,000 clinical trials'experience, the company has developed an RWE-based digital twin of human health and disease called"Digitome", which provides foundational RWE application for digital biomarkers, therapeutics, and population-level research insights |
| E-Nome | Consent Management | E-Nome | E-Nome is a secure platform to store and manage consent for access to health data. The company offers NSA-level end-to-end encryption with an immutable Blockchainaudit trail for a GDPR, HIPAA, and APP compliant data transfer system.<br>The Garvan Institute of Medical Research (Sydney) has signed a memorandum of understanding with E-Nome Pty Ltd, an Australian technology start-up driving the application of Blockchain technology to the secure storage of health records. |

**2.3 Telemedicine:-**

Telemedicine and e-health are two highly used domains, where clinical data is transferred remotely to a specialist (at a distant location) for an expert opinion. In these two online clinical setups, the patient's data is transferred either via a "store-and-forward technology", or by the means of online real-time clinical monitoring (e.g.Tele-monitoring, Telemetry). Using these online clinical settings, the patients are remotely diagnosed and treated by clinical experts using exchanged clinical data [17]. Blockchain-based telemedicine platform can validate professional identity and data integrity, ensure transparency, traceability, and incentivize the players to act fairly by providing incentive metrics such as reputation scores and crypto tokens. It can be expected that diagnostic services solely based on quantitative and qualitative interpretation of medical data in the absence of a patient will be first to adopt blockchain technology successfully. A large number of start-ups in this area corroborate this anticipation and many of these start-ups are targeting the services where the diagnosis of a medical condition is based on interpretation of patient-generated imaging data such as dermatology. DermoNet, a blockchain-based method is developed for assisting dermatology patients via an online dermatological consultation through a teledermatology monitoring system [14].

### 2.4 Billing Claims Management:-

Financial aspects of medical care are inherently important in the healthcare landscape. This area of financing aspect in healthcare is rife with inefficiencies, mostly related to the trust and transparency, which can potentially be optimized by the use of blockchain. Blockchain provides a mechanism for direct links between patients (one who makes claims) with the bearers (one who clears the claim), as there is trust inbuilt. Smart contracts can be used in the premium negotiating phases. Data regarding the current health status, medication usage, lifestyle, etc. tied through blockchain to evolving premiums, through smart contracts[17].

**Table No. 6: Companies and Initiatives That Use/Plan to Use Blockchain-Based Solution for Billing and Claim Management [17]**

| Initiatives | Description |
|---|---|
| Gem | Blockchain-based on Ethereum to streamline claim management in healthcare |
| Change Healthcare | Solution based on Hyper Ledger fabric 1.0 for claims and revenue management |
| HSBlox | A blockchain-based platform called SETU (Simplified Exchange and Transparency for Users) to provide solutions for claim management |
| Pokitdok | Provides Dockchain, a blockchain for financial data processing in aclinical setting, using features like smart contracts |
| Solve. care | The blockchain-based solution from Solve. care provides decentralized administration of health mostly concerning various health benefits program, preventing misuse and fraud for example |
| Health Nautica collaboration with Factom | This collaboration works on a blockchain solution for claim management and data record management in general |
| Smartillions | The solution from Smartillions used blockchain-based system for claims management with payment from an underlying pension fund, with the option of all transactions to providers also done with a digital asset |
| Robomed Network | Robomed in its blockchain-based solution ties payment for a medical procedure to expected clinical outcome, motivating the providers for a first time right medical treatment |
| Quantum Medical Transport collaboration with River Oaks Billing Associates | The collaboration is using the blockchain-based solution for medical billing payments, mostly to make such transactions secure |

**2.5 Blockchain Technology in Prescription Management: -**

Proper management of prescription is important to ensure the best healthcare service delivery. Misuse of the prescription has been rampant in recent years leading to large-scale problems like Opioid crisis. Many blockchain-based solutions have been proposed to remove the impediments on proper prescription management. BlockMedx is using an Ethereum based platform to securely manage prescription processes where all transactions are all securely stored in a blockchain. After a doctor issues a prescription to a patient, the designated pharmacist can verify it via blockchain before issuing the drugs. This system makes the management of controlled drug prescriptions like opioid efficient. Project Heisenberg is another example of an application using smart contracts on top of Ethereum to track prescriptions. It provides separate portals for patients, doctors, and pharmacies for their stake in the prescription process. Script Drop works on streamlining pharmacy delivery to patients. They deliver the drugs to the patients, relieving them of the burden of having to show up at the pharmacy for their medications. They also track the usage of medicine (adherence) using virtual assistants. ScriptDrop is using blockchain to track information about adherence and delivery. ScalaMed offers a blockchain-based solution for medical adherence and tracking of all prescriptions (including historical) around a patient-centric model. It describes the solution as a digital prescription inbox which will solve issues related to medicine mismanagement [17].

**2.6 Blockchain Technology in Genomics:-**

Genomic medicine opens the world of genetic data for providing an accurate diagnosis, prognosis, and appropriate treatment of several genetic diseases. Using genomic techniques, an individual's genetic information is profiled to determine their susceptibility to disease and appropriate treatment options for their personalized medicine. The human genome is comprised of approximately 3 billion base pairs amounting to about 1.5 GB of data. Using genomic mapping, scientists can gain a better understanding of the mechanisms involved in thousands of these rare diseases and common medical conditions. Using the mapping results, appropriate solutions and interventions can be developed. Scientists need to gather as much data as possible on disorders from those suffering from rare diseases. Poor access and the non-interoperability of such data have always been and continue to be a problem in healthcare. After the human genome project was completed, technological advances have

made it much more affordable to have one's genome sequenced, and genetic information profiled [23][24].

Genomics, in particular, has attracted a lot of interest from entrepreneurs and companies probably because of the recent popularity of personal genome sequencing, the importance of genomics data, and an immense possibility of its monetization. Personal genomics companies such as 23andMe and AncestryDNA monetize the genetic data by selling access to third parties such as labs and biotech companies. Several startups such as Encrypgen, Nebula Genomics, LunaDNA, etc. are developing blockchain-based genomics data-exchange platform or network. With the blockchain-based platforms, they claim to reduce the cost of genome sequencing, to give control of the data to patients, and to share the value captured from the monetization of the data to patients [17][25].

**2.7 Blockchain technology in Neuroscience:-**

The amount of news and analysis devoted to blockchain applications is increasing. Neuroscience activity included Modern neural technologies that seek to shape a new model that prohibits mechanical interaction with the surrounding infrastructure and allows one to control devices and data through mental commands. Such neural devices can interpret the patterns of brain activity and translate them into commands for controlling external devices, as well as detecting the current mental state of a person, based on data of their brain activity. These neural devices interpret the patterns of the brain and translate them into useful and powerful commands that are further used for controlling the external devices. These devices also monitor the condition of the brain of a person based on their data in the brain. This special task of reading and translating signals of the human brain is solved with neural interface devices that use several sensitive sensors, computing chips, and wireless communication medium. These devices read the electrical signals in the brain that are further transmitted to the controlled equipment that is a device placed on the head of a person [26]. There are complex algorithms and big data analysis behind all this neural process and they are aimed to use blockchain technology to store these brain signals in the neural interface device. Blockchain technology implemented in neuroscience applications such as brain augmentation, brain stimulation, and brain thinking. Digitizing and storing all the brain data requires a medium to store that data with security and reliability and blockchain technology provides the facility of brain data storage[20].

## 2.8 Blockchain Technology in Supply Chain Management:-

Supply Chain Management (SCM) is the process of overseeing and controlling the movement of goods and services from manufacture to the customer.it useful in transportation, tracking of customer orders [27]. In the pharmaceutical industry's current supply chain is somewhat complex and has limited transparency and thus is well positioned to potentially benefit from this technology. Blockchain technology adds transparency and efficiency in supply chain management and has potential applications in warehousing, delivery, payment, and all other transaction. Blockchain gives users access to real-time, trusted data, improve inventory management to reduce the need for intermediaries thereby reducing the complexity of the supply chain and therefore more secure transactions. It can even protect against theft and reduce opportunities for fraud or counterfeit products [28][29]. The mechanism of implementation of Blockchain technology in drug supply chain management is given in Figure 7.

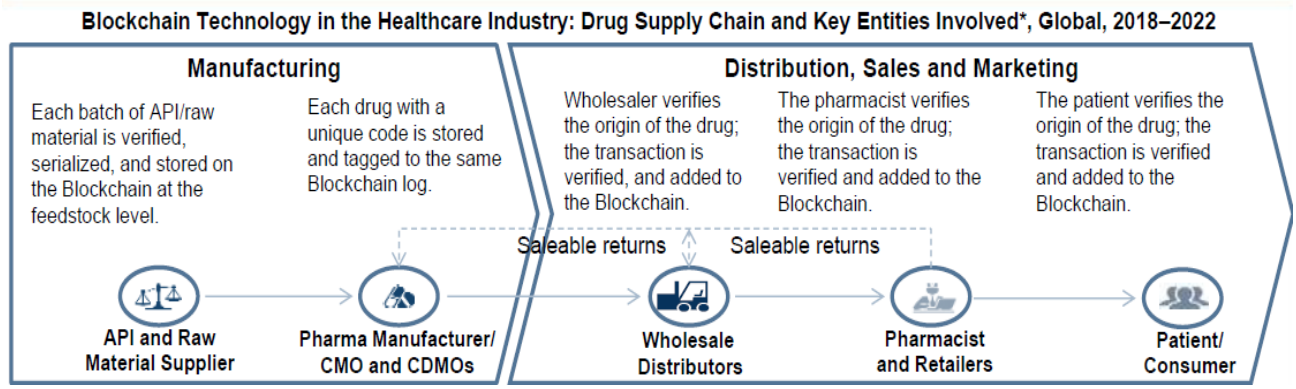


**Figure No. 7: Blockchain Technology in Drug Supply Management [21]**

Immutable hash (#) created on the Blockchain helps in automating serialization and geotagging the process across production, development, and testing by manufacturing facilities. Smart contracts automate the auditing of the outsourced contract manufacturing process and quality compliance with the Blockchain's verifiable source of truth. Blockchain-based smart contracts enable autonomous applications for due diligence, inventory management, and recall process. Blockchain can enable the implementation of an electronic regulatory submission interoperable system for marketing authorization submissions and updates to global regulatory authorities. The blockchain-based chain-of-custody log can track each step of the supply chain, starting from input raw material/API to the final drug delivered to the patient. It can maintain immutable historical records of products to detect saleable

returns, counterfeit and substandard products and identify the responsible party. It can verify supply chain provenance with real-time disclosure and alert systems of the entire product path, both up or down the supply chain. It can increase visibility for estimating the impact of various marketing alliances and promotional campaigns, such as rebates, co-paid ads, and coupons while boosting sales of individual drugs. Post-marketing processes, such as Adverse Drug Reactions (ADR) and safety monitoring are more efficient. Blockchain-based trusted workflows help run incentive-based medication adherence programs and reward them with crypto tokens on compliance. It helps in leveraging post-marketing research findings as an input for future R&D, especially for precision medicine. It provides new marketing channels (e.g., Online Sales, Direct to Consumer) [21].

**Table No. 7: Example Initiatives on the Use of Blockchain for Pharmaceutical Supply Chain Solutions [17]**

| Initiatives | Description |
|---|---|
| MediLedgerProject | Permissioned blockchain solutions to meet the track and trace regulation in pharmaceutical supply chain |
| Ambrosus | AMB-net, a blockchain-based IoT network for supply chain targeted for food and pharmaceutical industries |
| Modsense T1 from Modum | Blockchain-based tracking of temperature and environment conditions along the supply chain |
| Blockverify | Anti-counterfeit and transparency solution for supply chain with applications to pharmaceutical sector among others |
| DHL collaboration with Accenture | The initiative, dubbed as prototype solution service, uses blockchain to track pharmaceutical products throughout the entire supply chain |
| Imperial Logistics collaboration with One Network Enterprises | The solution from this collaboration is intended to improve supply chain security using the One Blockchain platform from the One Network Enterprises |
| Authentag | Provide distributed ledger technology from blockchain to provide tracking and verification services for pharmaceutical supply chain |
| EasySight Supply chain management/ Hejia | With the motivation to enable smaller company have reduced time for receiving payments, the blockchain-based solution from EasySight tracks drugs through the supply chain for complete transparency of trade records |
| GFT collaboration with MYTIGATE | The solution from this collaboration is a proof of concept on the use of blockchain to keep track of pharmaceuticals. SAP has combined blockchain technology with their ATTP (Advanced track and trace for pharmaceuticals) to solve supply chain issues |

| | |
|---|---|
| | considering new regulatory requirements |
| IEEE Pharma Supply Blockchain Forum | A general podium for multiple stakeholders to initiate and discuss the potential usage of blockchain for pharmaceutical supply chain solutions |

**3. Key Challenges for Implementation of Blockchain Technology in Healthcare Sector:-**

Blockchain technology is an emerging technology and is being used in various sectors with its potential benefits and opportunities to revolutionize the digital world. But the technology is still immature and has its challenges that should be considered to solve in future implementations. Here we have some major challenges discussed here as under [20].

- **Nascent Technology**:- Challenges around the technical understanding of decentralizing cryptosystems and the lack of proven commercial prototypes are likely to limit the large-scale adoption of Blockchain systems.

- **Standardization and Terminology Issues**:- Despite Blockchain's potential to disrupt healthcare workflows, it is critical to deal with disparate terminologies and conflicting standards in current healthcare systems.

- **Inefficiencies in The Current BlockchainSystem**: - The verification and validation with Bitcoin requires high computing energy and cannot be scalable for more complex healthcare data.

- **Industry Inertia to New Technology**:- The healthcare industry's inertia to implement new technologies and, more importantly, conflicting interest among incumbents owning health data in silos are likely to be big hurdles.

- **Integration Concerns**: - There are technical, operational, governance, and economic challenges in integrating a Blockchain system with existing healthcare IT systems. Companies need to access their strategic imperatives and prioritize Blockchain system implementation across select use cases[21].

- **Interoperability**:- Blockchain has the major issue of interoperability. As interoperability enables multiple users to send and share data and transactions in the network without any intermediary, but sometimes standards are ignored in the building of blockchain to get more

freedom in the network and this causes interoperability and communication issues in the blockchain network.

- **Uncertainty**:- The blockchain concept is still young and cannot be used without certain specifications and surety. At this time a few successful initiatives are utilizing this modern technology. This challenge is imperative to consider for the successful implementation of blockchain in uncertain situations.

- **Storage Capacity**:- In the healthcare industry, there is a massive amount of medical data, images, documents, and lab results and it requires a significant space for storing all these types of data. Every node in the blockchain network has a copy of all records; this can lead to the shortage of storage capacity of current blockchain technology.

- **Cost**:- The cost establishment and maintenance of healthcare records using blockchain is unknown to many of the organizations and no one can adopt the technology without knowing the exact cost and expenses [20].

## CONCLUSION

Blockchain technology has potential applications to overcome various challenges faced by the healthcare industry. The strongest potential of blockchain technology is to provide security, integrity, decentralized access to the patients' records, availability of records, and authentication of accurate data storage due to its salient features of decentralization, immutability, transparency, and interoperability. The utilization of blockchain in the healthcare industry has many benefits for several individuals including patients, doctors, physicians, healthcare providers, clinical researchers, external healthcare entities, biomedical and neurology experts In this document, we reviewed major use cases of blockchain such as healthcare data management, supply chain management in the pharmaceutical industry, medication adherence, billing/claims management, analytics, etc. Examples of organizations developing blockchain-based applications for these use cases were also presented. The proposed applications range from moon-shot projects trying to build a complete decentralized health care ecosystem to specific applications such as data provenance, counterfeit drug identification, consent management, etc. Despite the immense potential of blockchain technology and an enormous amount of interest around it, we found that its impact on healthcare is minimal and is still in the early days. Most of the blockchain-based healthcare solutions are still in the form of novel concepts represented by whitepapers, prototypes, or

only a very small number of working products with a limited user base. However, the field is evolving rapidly; we anticipate a significant positive impact of blockchain in healthcare in the future.

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