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The benefits and threats of blockchain technology in healthcare: A scoping review

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ABSTRACT

Background: The application of blockchain technology is being explored to improve the interoperability of patient health information between healthcare organisations while maintaining the privacy and security of data.
Objectives: The objective of this scoping review is to explore and categorise the benefits and threats of blockchain technology application in a healthcare system.
Methods: Databases such as PubMed, CINAHL, IEEE, Springer, and ScienceDirect were searched using a combination of terms related to blockchain, healthcare, benefits and threats. Backward-reference list checking was conducted to identify other relevant references. Study selection process was performed in three steps based on PRISMA flow diagram. Extracted data were synthesised and presented narratively using tables and figures.
Results: The search resulted in 84 relevant studies that have been conducted of which only 37 unique studies were included in this review. Eight benefits of blockchain were categorised in either patient related-benefits (security and authorisation, personalised healthcare, patients' health data tracking, and patient's health status monitoring) or organisational-related benefits (health information exchange, pharmaceutical supply chain, clinical trials, and medical insurance management). Meanwhile, eight threats of blockchain were categorised into three groups: organisational threats (installation and transaction costs, interoperability issues, and lack of technical skills), social threats (social acceptance and regulations issues), and technological threats (scalability issues, authorisation and security issues, high energy consumption, and slow processing speeds).
Conclusion: Blockchain is a viable technology that can improve the healthcare data sharing and storing system owing to its decentralisation, immutability, transparency and traceability features. However, many healthcare organisations remain hesitant to adopt blockchain technology due to threats such as security and authorisation issues, interoperability issues and lack of technical skills related to blockchain technology.

1. Introduction

1.1. Background

Blockchain technology was first introduced by Satoshi Nakamoto in 2008 through his Bitcoin cryptocurrency technology [1]. Since then, blockchain technology has been used in various industries such as business, finance, and healthcare. In healthcare system, blockchain technology has a potential in protecting patient information [2].

Blockchain is an advanced data structure that comprised of a growing list of records called blocks [3]. There are many characteristics that make blockchain technology useful for application in healthcare which include immutability, decentralisation, transparency and traceability [4]. Immutability can be defined as the persistence of the blockchain ledger and the ability to keep the data unaltered and unchanged, while decentralisation refers to a process where there is no single authority of any transaction that occurs within the system. Meanwhile, transparency is where anyone in the network can view all the information stored within a blockchain transaction, whereas traceability refers to the ability to trace the data with verifiable timestamps [3,4].

A block in a blockchain network contains four elements, which are: information, hash (identification number) of the current block, hash of the former block, and timestamp [1,4], where each new block is connected to its former block [1]. There are different design types of blockchain technology, namely public (permissionless), private (permissioned) and hybrid blockchains [3]. Public blockchains are designed to be open source and allow anyone to participate in the blockchain. Proof of Work (PoW) is the most well-known algorithm used for public blockchains [1]. In addition, all transactions executed in a public

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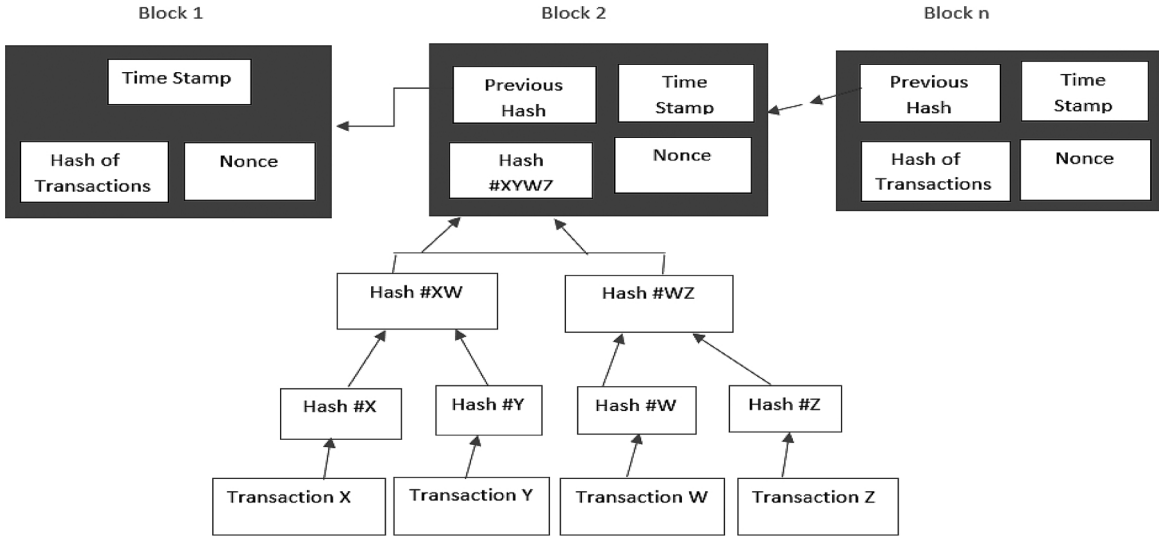

Fig. 1. Common structure of Blockchain [1].

blockchain are completely transparent to all individuals participating, and hence there is no control by any single user or entity [3]. In contrast, for private blockchains, participants need to request for permission to join the network, and all transactions are available upon access provided by the authorised participants only, while hybrid blockchains are flexible where there is an ability to choose certain data to be made available for the public or data to be kept private [3]. An overview of a blockchain structure is as shown in Fig. 1.

1.2. Research objective

Little is known about the benefits and threats of blockchain technology in healthcare. Hence, the purpose of this scoping review is to explore and summarize the main benefits and threats of blockchain technologies within a healthcare context, as reported in the literature. In the next section, we deliberate the methodology used in this study. Section 3 shows findings of the study. We discuss the findings and provide research and practical implications in Section 4. The conclusion of this review is shown in the last section. In conducting the review, we followed the JBI methodology for scoping reviews [5].

2. Methods

2.1. Eligibility criteria

All primary studies that reported on benefits and/or threats of blockchain in healthcare from the year 2017 onwards were included in this review except information from newspapers, literary magazines, webzines and conference abstracts. The selection of the time period was attributed to the recent use of blockchain technologies in healthcare and the increase in the available literature since 2017 [6]. Studies that were reported in a language other than English were excluded. Research on blockchain implementation methods or combination of blockchain and other technologies blockchain technology training and public awareness studies were excluded. The study eligibility criteria are summarized in Table 1.

2.2. Search strategy

Research paper publishing platforms such as PubMed, CINAHL, IEEE, Springer and ScienceDirect were used as the search sources for this review. In addition to these databases, backward-reference list checking was carried out to identify additional relevant studies. The bibliographic databases were searched using the following combination of search terms: blockchain* AND (health* OR medical*) AND (challenge* OR obstacle* OR issue* OR disadvantage* OR threat* OR benefit* OR advantage*). The search was conducted between the 6th of October 2019 and the 23rd of October 2019 and was repeated before submission of this review paper (early 2020) to identify new studies being published.

Table 1
Inclusion and exclusion criteria.

Criteria	Specified Criteria
Inclusion	• Studies that address benefits and/or threats of blockchain in healthcare • Studies published from 2017 onwards • Primary studies
Exclusion	• Studies reported in a language other than English • Information from magazines, newspapers, conference abstracts • Studies that targeted the implementation methods of blockchain • Studies that targeted training and raising awareness of healthcare providers on the adoption of blockchain • Studies that merged blockchain and other technologies

2.3. Study selection process

Filtering process of studies retrieved from the database was performed in three phases: (i) identification phase, where search queries were applied to the databases followed by the removal of duplicates; (ii) screening phase, where titles and abstracts of articles were screened to exclude irrelevant articles; (iii) eligibility phase, where the full-texts of articles were read to assess their relevancy to this study. The second and third phases were conducted independently by two reviewers. If a disagreement arose between the reviewers, a third reviewer was consulted to assist in decision-making of inclusion or exclusion of the study.

2.4. Data extraction and data synthesis

The two reviewers independently extracted the following data from the included articles: author name, year of publication, country of publication, publication type and findings. Subsequently, narrative synthesis of the extracted data was performed.

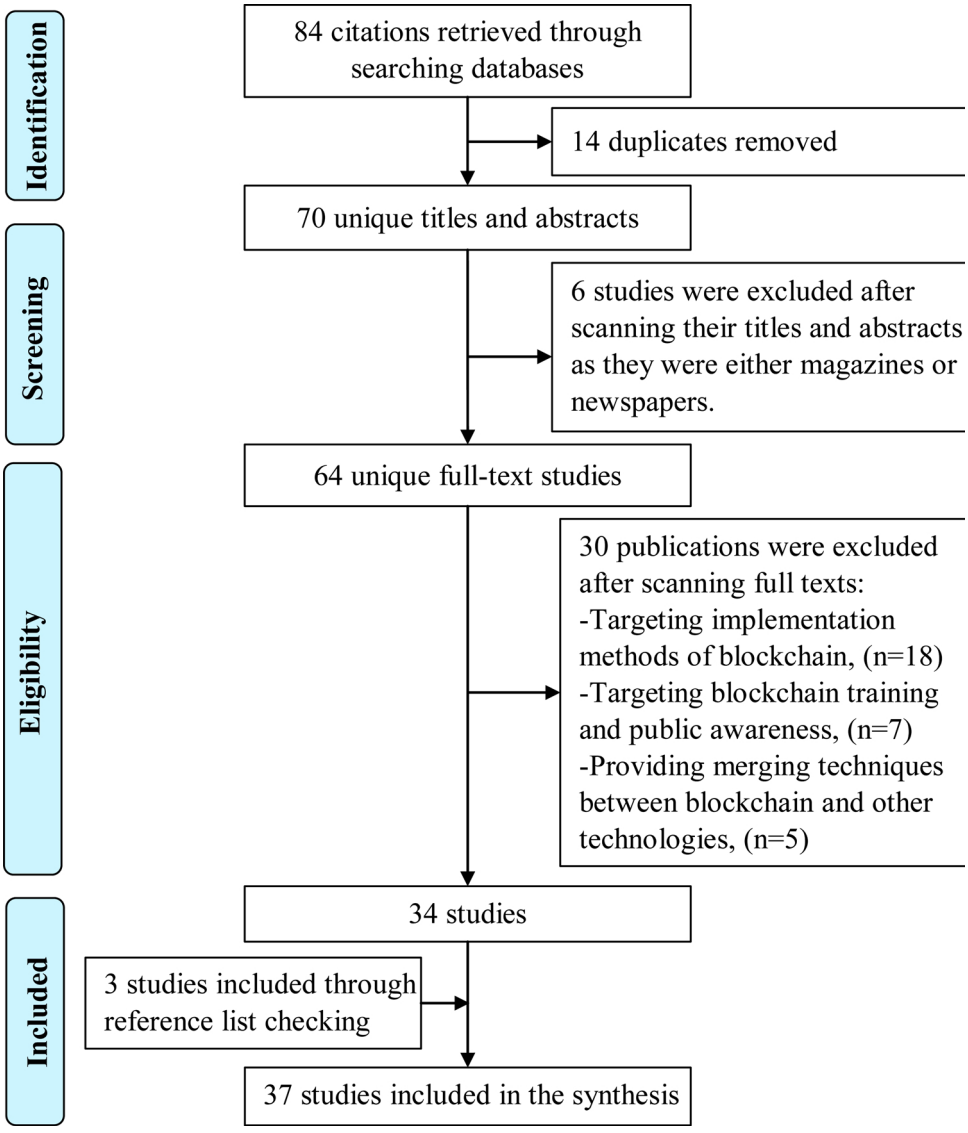

Fig. 2. Study selection process.

Table 2
Characteristics of the included studies.

Characteristics	Number of studies			
Year of publication	2017: 1	2018: 11	2019: 22	2020: 3
Country of publication	USA: 16 Spain: 2 Pakistan: 1 Malaysia: 1	China: 3 Germany: 1 Turkey: 1 Finland: 1	India: 3 Korea: 1 Kenya: 1 Brazil: 1	UK: 2 Sweden: 1 UAE: 1 Australia: 1
Type of publication	Journal article: 27	Conference proceeding: 8	Book chapter: 2	
Reported outcome	Benefits: 9	Threats: 9	Benefits & threats:19	

3. Results

3.1. Search findings

The study selection process is illustrated in Fig. 2. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flow diagram was used to present the three filtering stages as indicated in section 2.3. As a result of an initial search, a total of 84 studies were retrieved from the five databases included in this study. From the 84 studies, 70 unique articles were selected after removing 14 duplicate articles. Upon completion of titles and abstracts screening, 6 articles from magazines and newspapers were found and excluded resulting in 64 articles. Consequent assessment of full-text articles for further screening led to exclusion of 30 articles due to the study contents that focused on the implementation methods and architecture of blockchain in healthcare, significance of training sessions and public awareness of blockchain technology in healthcare; and combination of blockchain and other technologies which did not fulfil the inclusion criteria of this study. Three additional studies were added through the backward reference list checking. Overall, 37 studies were included in this review.

3.2. Characteristics of the included studies

As presented in Table 2 , few studies were published in 2017 (n = 1) and 2020 (n = 3), while numerous studies were published in 2018 (n = 11) and 2019 (n = 22). The selected studies were published in more than 15 countries, however, 43 % (n = 16) of the studies were published in the United States of America (USA). The included articles were published in peer-reviewed journals (73 %, n = 27), conference proceedings (22 %, n = 8), and books (5%, n = 2). Equal percentage was noted for studies reported individually on the benefits and the threats of

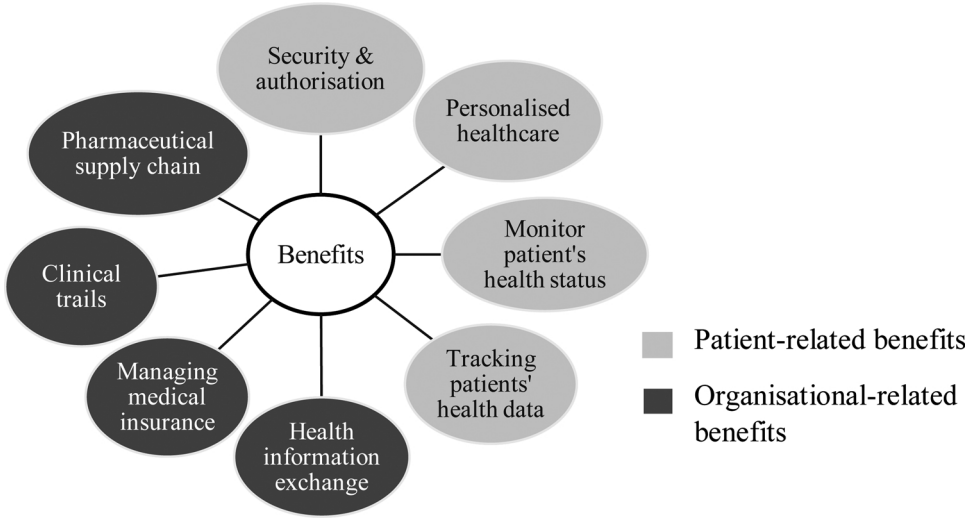

Fig. 3. Benefits of blockchain technology.

blockchain in healthcare where each accounted for 24 % (n = 9). However, 51 % (n = 19) of the studies reviewed both the benefits and the threats of blockchain in healthcare. Details of each study characteristics are displayed in Appendix 1.

3.3. Findings of the included studies

3.3.1. Benefits of blockchain technology in healthcare

Eight benefits of blockchain technology are demonstrated in Fig. 3. The benefits were categorised into patient-related or organisational-related benefits. Four patient-related benefits were reported in 18 studies [3–5,7–21] while four organisational-related benefits were discussed in 19 studies [1,5–7,9–13,15,17,22–29].

3.3.1.1. Patient-related benefits. Security and authorisation is one of the patient-related benefits of blockchain technology. Eleven studies reported that the use of blockchain can enhance the security of health information by securing patient data over decentralised peer-to-peer networks and placing the patient at the centre of the system [3–5,7–14]. Out of eleven studies, two studies reported that blockchain can minimise the incidents of data breach as the network does not suffer from a single point of failure [10,11]. Besides, blockchain was also recognised as an authentication provider to verify user access for health-related data services using only one identity, as reported by two studies [11,15].

Apart from security and authorisation, six studies reported that blockchain can contribute to personalised healthcare where it allows healthcare providers to embrace the concept of shared medical records to create and share personalised healthcare plans for patients [3,7,16–19].

Another five studies confirmed that blockchain has the ability to assist physicians in tracking patient data more easily by using time-stamps that are recorded for each transaction [10,11,15,17,20]. Besides, five studies agreed that the technology enabled monitoring of patients health status [7,9,13,18,21], where this feature is also important for critically ill patients as physicians can closely monitor the patients and take immediate action in case of an emergency, as attributed by two studies [18,21].

3.3.1.2. Organisational-related benefits. Besides patient-related benefits, blockchain technology is known for organisational-related benefits. Six studies reported that blockchain can provide a secure sharing of patient information with healthcare organisations [7,10–12,22,23]. Another three more studies focused on the decentralisation feature which was found to be the real contributor to achieve a seamless health information exchange between the healthcare organisations [5,7,24]. As an example of this, blockchain has been reported by one study that it can allow for a reliable and secure exchange of the health information related to medical imaging across the entire blockchain network [25].

As reported by five studies, blockchain technology also benefited organisations by facilitating clinical trials management necessary for drug testing [6,9,12,23,24]. Specifically, three studies found that security requirements that need to be addressed in the context of clinical trials management can be comfortably satisfied by utilising private blockchain [9,12,24].

Not only that, traceability feature of blockchain was found by eight studies to facilitate pharmaceutical supply chain management [6,9,10,13,17,23,24,26] where blockchain utilisation was noted to prevent incidents of counterfeit drugs, as proven by three studies [23,24,26].

Ten studies reported that other than clinical benefits, blockchain has non-clinical benefits such as management of medical insurances [1,7,15,20,22–24,27–29]. The previous studies attributed immutability for being the most important feature of blockchain that assisted in the improvement of the medical insurance industry. Besides, three studies found that blockchain technology allowed organisations to store and backup medical insurances since the copies of the shared ledger are stored across users' computers [22–24,29].

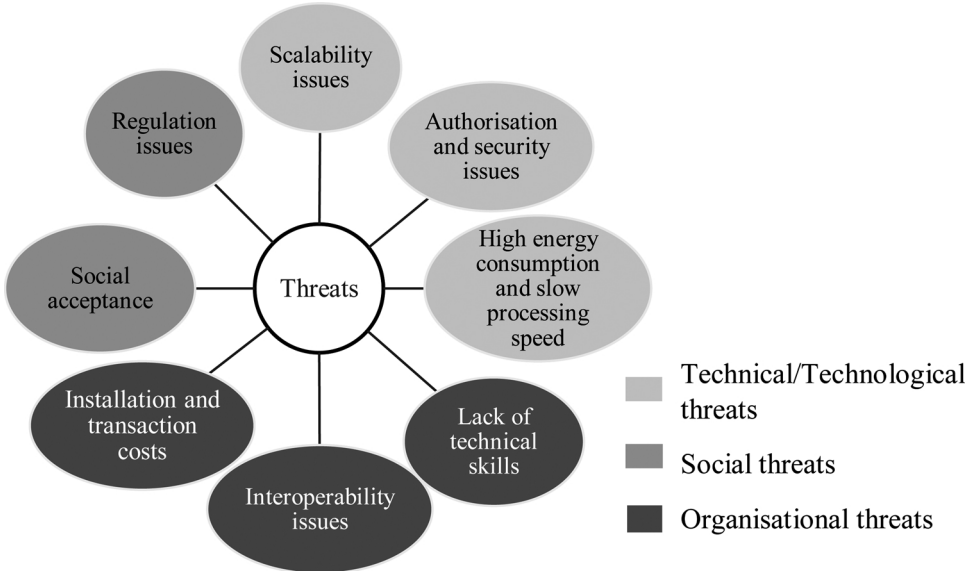

Fig. 4. Threats of blockchain technology.

3.3.2. Threats of blockchain technology in healthcare

Eight threats of blockchain technology were identified from the included studies (Fig. 4) where the threats were categorised into organisational, social, or technical/technological threats. Three types of technical/technological threats were mentioned in 13 studies [2,5,7,11,14,15,17,23,29–33], two types of social threats were found in 14 studies [4,5,7,9–11,15,16,19,22,25,28,31,34] while three organisational threats were reported by 14 studies [2,6,7,9,10,13,15,17,20,28,33,35–37]. Details about the identified threats were discussed in the following sub-sections.

3.3.2.1. Technical or technological threats. Five studies mentioned about the scalability of blockchain technology [2,7,17,29,30]. The scalability issue of blockchain technology was related to the limited rate of processing transactions executed per second in the network, as reported by [7]. In addition, two studies pointed out that scalability constraint was ascribed to the trade-off between the transaction volume and the computer power required to handle the transactions [2,29].

Seven studies have indicated that authorisation and security were inter-related issues in blockchain technology [5,7,15,17,23,30,31]. It was reported by three studies that blockchain technology is susceptible to cyber-attacks such as domain name system (DNS) attack and mempool attacks (i.e., blocks were flooded with transactions) where the attacker took control over the majority of blockchain networks [15,17,30].

Eight studies reported other key challenges associated with the acquirer of public blockchains particularly, include high energy consumption and slow processing speed [2,11,14,15,23,30,32,33] due to large number of users joining the network.

3.3.2.2. Social threats. As stated by three studies, major challenge faced in the adoption of blockchain technology was the societal acceptance [4,11,31]. Nine studies [5,7,9,10,15,16,19,22,25] showed that the decentralisation of medical data and the disengagement of a trusted third party make it difficult for the legal authorities to issue access highlighting privacy as a legitimate concern. Four studies also emphasised on the lack of governance regulations and guidelines which can prevent blockchain implementation within healthcare [10,25,28,34].

3.3.2.3. Organisational threats. From the organisational perspective, eight studies reported that interoperability as one of the major issues of blockchain implementation in the area of healthcare [2,6,7,9,20,35–37]. Interoperability issue was attributed by three studies to the lack of trust between parties and limited open standards that cause difficulties for a comprehensive exchange of health information between healthcare organisations [35–37].

Another problem identified by one study was the maintenance of an integrated pharmaceutical supply chain between the stakeholders for the blockchain with lacking essential technical skills and IT professionals who are experts in operating the technology [15].

In addition, although blockchain can save cost in the long run, the initial installation cost is fairly high [10,13,17,28,33]. According to one study [33], the Bitcoin protocol requires a processing fee that can exceed USD 0.30 for each transaction.

4. Discussion

4.1. Principle findings

Benefits and threats of blockchain technology in the healthcare industry as reported in the literature were reviewed and presented in this paper.

Benefits were classified into two groups: patient-related benefits and organisational-related benefits. For patient-related benefits, blockchain can function as an authentication provider for users accessing the

network by using only one identity [11,15]. This is advantageous for private (permissioned) blockchains exclusively as users can register their identity on the blockchain network only once and the registered identity attributes will be hashed and stored in the entire blockchain node [11]. As a result, users will not have to register their identity again for future access. Besides, utilisation of blockchains allows healthcare providers to embrace the concept of shared database that is able to create sharable personalised healthcare plans for patients. Consequently, this can easily contribute to the facilitation and establishment of personalised health plans to categorise the patients according to their common genomic data, age or gender [17].

Moreover, traceability feature of blockchain enables patient tracking as every Bitcoin transaction is recorded with a timestamp that is verified and maintained by all the computer nodes participating in the blockchain network [17]. As a result, physicians will be able to trace incorrect treatment decisions given to patients.

Effective patient monitoring is another benefit provided by blockchain technology especially for critically ill patients as this technology assists physicians in making adequate medical-related interventions [18,21]. To achieve this, wearable devices of patients such as smartwatches, smartphones and smart glasses are required to be connected to the healthcare provider's blockchain network [7,9,13,18,21].

As for the organisational-related benefits, blockchains have the ability to provide a secure sharing of patient information between healthcare organisations. Currently, the centralised cloud-based systems are the traditional health information exchange platforms to share electronic health records across healthcare organisations. However, these systems do not guarantee data integrity and security since trust in a single authority is required [5,7,24]. Unlike permissioned blockchains that promote seamless health information exchange, the group of authorised healthcare organisations participating in the private network are able to share and access the information stored in the blockchain in a secure and reliable mode. Other studies emphasised on the significance of utilising blockchains to facilitate the management of clinical trials as the research contain highly sensitive patient related information [9,12,24]. Private (permissioned) blockchains can be utilised for this case as immutability, traceability and authenticity for accessing healthcare data are allowed which will assist in facilitating the process of regulatory approvals for new treatments as the evaluation of the clinical trials will be conducted in a more seamless state.

Furthermore, the traceability feature of blockchains was reported to play a significant role in managing the pharmaceutical supply chain. In particular, blockchains are able to identify the origin of the data to support pharmaceutical companies in tracking the supply of products [9,10,13,17].

Previous reviews have demonstrated the applications of blockchain in healthcare such as the personal health record maintenance and remote patient monitoring. The use of blockchain in telemedicine systems, remote patient monitoring combined with the internet of things and medical insurance were also discussed in other reviews [38,39].

Although there are various advantages of blockchain technology, threats do exist as well. In this review, threats were classified into three groups which were technological, social and organisational threats. Three technological threats were identified which were scalability issues, authorisation and security issues, and high consumption of power and energy. Scalability is considered to be the most critical technical threat faced in blockchain technology application. Scalability issue has become a huge concern for public blockchain application as there is no control on the number of users joining the network. Additionally, problems arise when connecting wearable devices for the purpose of monitoring blockchain networks where the data generated from these sensors grow in an exponential rate [7].

Also, blockchain is prone to cyber-attacks where the attackers can take control over the blockchain network which can lead to a disaster if the attackers interrupt, prevent or even reverse transactions already confirmed within the network. In addition, high energy consumption was highlighted in this review as a threat since it relates to the Proof of Work based blockchain (public blockchain) use which is a technique of mining that consumes a great amount of energy. This problem exacerbates as more users joined the blockchain network and the number of transactions executed per second increased [17]. Another primary social threat identified was the lack of regulations issued by legal authorities for blockchain technologies. Decentralisation and disengagement of trusted-third parties have prevented the establishment of these regulations.

Meanwhile, organisational threats were mostly related to interoperability issues, lack of technical skills for integrating pharmaceutical supplies, installation and transaction costs. Interoperability was considered as one of the major challenges for blockchain technology adoption in healthcare due to the lack of trust between healthcare organisations and lesser number of IT professionals available to implement blockchain technology. Lack of sufficient technical skills and capabilities while implementing blockchain technologies may lead to disastrous consequences.

4.2. Strengths and limitations

4.2.1. Strengths

This review provides valuable insights into the benefits and threats related to the use of blockchain in healthcare, particularly in medical data sharing and storing. This review is expected to assist stakeholders, funding agencies, and organisations to have a better overview of the current positive and negative contributions of blockchain in the healthcare field. The study selection and data extraction process were carried out independently by two reviewers increasing the validity and reliability of the work. To minimize the risk of publication bias, backward-reference list checking was conducted to retrieve grey literature. Benefits and threats of blockchain identified in this review were categorised into groups which were more organised and understandable.

4.2.2. Limitations

Results of this review must be interpreted with caution due to multiple limitations. First, the findings of this scoping review are mainly intended for healthcare entities, which are relatively not applicable to other domains such as business and marketing. Second, for practical reasons, the search strategy was restricted to studies reported in the English language which could have overlooked other benefits and threats reported in other studies reported in a non-English language.

4.3. Research and practical implications

4.3.1. Research implications

Multiple gaps in the research related to the use of blockchain technologies in healthcare were noted. Few studies attempted to

identify assets related to blockchain beyond privacy, security, and management issues. Besides, a gap in the research discussing the practical immutability functions in the electronic health records was found as the data written in the blockchain cannot be removed [38]. This can lead to a number of valid concerns for stakeholders considering adopting this technology for their healthcare systems. Not only that, there is a lack of resources in the literature that draws conclusions on the benefits of two types of designs which are permissioned blockchain being private and permissionless blockchain being public concerning its applicability for organisations [29].

Future research may include investigation of direct benefits and threats of each type of blockchain design including permissioned, permissionless, and hybrid and assessment of their effectiveness in the healthcare domain. Several research gaps were observed in terms of policies and authorisation guidelines related to blockchain utilisation besides social acceptance of blockchain technology within healthcare organisations which can be considered for future research. As most of the findings found were based in the US setting, more research should focus on other regions of the world for valid interpretation for global use and provide better understanding of blockchain technology application within the healthcare field.

4.3.2. Practical implications

There are a number of practical issues that need to be considered when implementing blockchain technologies. First, further work is needed to investigate how blockchain technology can help protect the integrity of medical information. Second, the security risks of blockchain implementation within healthcare organisations should be further examined. A major concern reported in the literature is finding the relevant technical talent that can implement, manage, and resolve technical issues relating to the blockchain technology.

5. Conclusion

Blockchain is a growing technology for application in the healthcare sphere that comes with a number of viable sharing and storing characteristics including decentralisation, immutability, transparency and traceability. The threats of blockchain technology utilisation within healthcare field include scalability issues, interoperability, lack of technical expertise, security, and authorisation. It is important to demonstrate evidence related to differences between each blockchain design in future work as there is a gap in research guiding healthcare organisations to implement blockchain design types which are public, private and hybrid.

Appendix A

Table A1

Authors' contributions

The study was developed under the guidance and supervision of Dr. Alaa Abd-alrazaq and Dr. Mowafa Househ. All authors have contributed in methodology development and review. Anjanarani Nazeemudeen was responsible for the background, introduction and conclusion, while Asma Hassan developed the discussion section. Israa Abu-elezz was responsible for developing the study selection process and investigating the characteristics of the studies. All authors contributed to the search findings of the results.

Summary table

What was already known on the topic

- Blockchain is a technology that can be of benefit to the healthcare industry improving interoperability standards while maintaining the privacy and confidentiality of patient records.
- Challenges related to security, privacy, scalability and interoperability is still one of the most obvious vulnerabilities encountering the application of blockchain in healthcare.

What this study added to our knowledge

- We summarized the benefits and threats related to blockchain technology use
- Studies mainly highlight technical know-how as a major hurdle for the implementation and use of blockchain technology in healthcare.
- It is important to pay attention and investigate the social acceptance of blockchain technology use in healthcare

Declaration of Competing Interest

The authors report no declarations of interest.

Table A1
Characteristics of each included study.

Author	Year	Country	Publication Type	Findings	
				Benefits	Threats
Pandey et al	2020	Kenya	Journal Article	Pharmaceutical supply chain, clinical trials, health information exchange	Slow processing speed
Hylock & Zeng	2019	USA	Journal Article	security & authorization, interoperability, clinical trials	————
Beinke et al	2019	Germany	Journal Article	Managing medical insurances	Scalability issues, high energy consumption, slow processing speed, social acceptance & regulation issues, lack of technical skills
Esmaeilzadeh & Mirzaei	2019	USA	Journal Article	Security & authorization, tracking patients' data, Pharmaceutical supply chain, health information exchange	Slow processing speed, social acceptance & regulation issues, lack of technical skills
Tanwar et al	2020	Brazil	Journal Article	Health information exchange	Installation & high transaction costs
Zheng et al	2019	Spain	Journal Article	————	High energy consumption, transaction costs
Mackey et al	2019	USA	Journal Article	Clinical trials, Pharmaceutical supply chain	Interoperability issues
Hannah & Huang	2018	USA	Journal Article	Security & authorization, personalized healthcare, tracking patients' data, health information exchange, Pharmaceutical supply chain	Social acceptance & regulation issues, transaction costs
Shuaib et al	2019	United Arab Emirates	Journal Article	Personalized healthcare, tracking patients' data, Pharmaceutical supply chain	Scalability issues
Maesa et al	2020	USA	Journal Article	————	security & authorization issues, high energy consumption
Boulos et al	2018	United Kingdom	Journal Article	Security & authorization, monitor patients' health status, clinical trials, Pharmaceutical supply chain	Interoperability issues, social acceptance & regulation issues,
Ornes	2019	USA	Journal Article	————	High energy consumption
Kassab et al	2019	USA	Conference Proceeding	————	Interoperability issues
Monrat et al	2019	Sweden	Journal Article	————	Scalability issues, interoperability issues, high energy consumption,
Vora et al	2018	India	Conference Proceeding	Security & authorization	High energy consumption
Kumar et al	2018	Finland	Conference Proceeding	Health information exchange, clinical trials, Pharmaceutical supply chain, administrative processes	————
Kassab et al	2019	USA	Conference Proceeding	Managing medical insurances	Interoperability issues
Shah	2018	India	Conference Proceeding	Security & authorization, personalized healthcare	————
Shahnaz et al	2019	Pakistan	Journal Article	Security & authorization,	Social acceptance & regulation issues
Zhang et al	2018	USA	Book Chapter	Managing medical insurances, health information exchange, tracking patients' data	Interoperability issues,
Onik et al	2019	Korea	Book Chapter	Supply chain	————
McGhin et al	2019	USA	Journal Article	Health information exchange, security & authorization	Social acceptance & regulation issues, security & authorization issues
Sheng et al	2019	China	Journal Article	————	Social acceptance & regulation issues
Gökalp et al	2018	Turkey	Conference Proceeding	Administrative processes, managing medical insurances	Social acceptance & regulation issues, installation & high transaction costs
Kaur et al	2018	India	Journal Article	Administrative processes, health information exchange	Social acceptance & regulation issues
Patel	2018	USA	Journal Article	Health information exchange	Social acceptance & regulation issues
Leeming, et al	2019	United Kingdom	Journal Article	Health information exchange, personalized healthcare	Social acceptance & regulation issues
Clim et al	2019	Malaysia	Conference Proceeding	Managing medical insurances, health information exchange, personalized healthcare	Scalability issues
Alonso et al	2019	Spain	Journal Article	Administrative processes	Scalability issues
Greenberger	2019	USA	Journal Article	Personalized healthcare	Social acceptance & regulation issues
Zhou et al	2019	China	Journal Article	Personalized healthcare	————
Angraal et al.	2017	USA	Conference Proceeding	security & authorization	————
Prokofieva & Miah	2019	Australia	Journal Article	————	Social acceptance & regulation issues, Security & authorization issues
Kuo et al	2019	USA	Journal Article	————	Interoperability issues
HIPPA	2019	USA	Journal Article	Managing medical insurances	————
Fan et al	2018	China	Journal Article	————	Interoperability issues
Clauson et al	2018	USA	Journal Article	Supply chain, clinical trials, security & authorization	Social acceptance & regulation issues, interoperability issues

Appendix B. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijmedinf.2020.104246.

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