Blockchain-based Healthcare: Trend Mapping through Bibliometric Analysis

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Abstract— **Blockchain technology has gained significant attention in the healthcare industry due to its potential to address critical challenges related to data security, interoperability, and patient privacy. Due to the growing research in this area, it has become essential to gain a comprehensive understanding of the evolving landscape and identify the current state of research and future directions in the field of blockchain technology in healthcare. This paper aims to achieve this by conducting a bibliometrics analysis to map the trends and research landscape of blockchain-based healthcare. The bibliometric analysis of scholarly articles and conference papers published in the Scopus database was used to identify the yearly trend of publications, influential authors, leading countries, prominent research institutions, and top journals in this field. Additionally, co-occurrence keywords were analysed to explore the key themes and identify emerging trends and future research directions in blockchain-based healthcare. This study provides valuable insights for researchers, practitioners, and policymakers interested in understanding the current state and future prospects of blockchain technology in the healthcare domain. It also serves as a primary reference source for further studies in this area.**

Keywords— blockchain, healthcare, bibliometric analysis, trend mapping, Scopus database.

I. INTRODUCTION

Blockchain technology (BCT) was initially introduced as the underlying technology for cryptocurrencies [1]. BCT enables the secure storage of transactions in a peer-to-peer network through a decentralised ledger [2]. It enhances transaction transparency and verification. The main objective of BCT is to facilitate secure transactions between two parties without the need for intermediaries [3]. The emergence of BCT as a transformative innovation has the potential to revolutionise numerous industries, including healthcare [4]. The current state of healthcare records is characterised by size, complexity, duplicates, varying names and identifiers, and distributed availability across different networks [5]. Ensuring healthcare security has become crucial to safeguard data and prevent illicit activities. Unauthorised access to patient data can lead to misuse or unauthorised disclosure, compromising patient privacy [6].

The decentralised and immutable nature of blockchain offers opportunities to address longstanding challenges in healthcare, like data security, privacy, and interoperability [7]. By providing a transparent and tamper-resistant ledger, blockchain can enable secure data exchange, streamline administrative processes, and empower patients to have greater control over their health information [8]–[10]. As the healthcare sector continues to grapple with issues related to data breaches, fragmented health information systems, and inefficient processes, the adoption of blockchain has gained significant attention as a means to address these problems [8].

It is worth noting that the potential applications of BCT in healthcare are numerous [13]. By utilising BCT, healthcare systems can experience improved security in electronic health record management through the implementation of a tamper-proof and decentralised recordkeeping system [5]. Additionally, BCT facilitates the secure and efficient exchange of patient data between healthcare providers and patients, ultimately enhancing care coordination and patient outcomes [14]. Moreover, the adoption of BCT enhances transparency and efficiency within healthcare systems [5], [11]. Researchers predict a substantial global blockchain market increase from 2020 to 2027 [15]. This growth is expected to bring about enhanced transparency, improved traceability, strengthened privacy and security, increased efficiency, and reduced costs [16]. Furthermore, BCT facilitates seamless decision-making by enabling simultaneous assessment from all stakeholders involved, thereby fostering trust [17]. BCT's inherent features are believed to have the potential to address current challenges within the healthcare industry [18].

As a result, there has been a growing interest in exploring the applications of BCT in healthcare. Numerous studies have explored BCT's potential applications, benefits, and challenges in healthcare settings [19]–[22]. However, with the rapid growth of research in this domain, gaining a comprehensive understanding of the evolving landscape and identifying the current state of research and future directions in the field of BCT in healthcare becomes crucial. To achieve this goal, the utilisation of bibliometric analysis proves to be a useful tool. It

allows for a systematic and quantitative analysis of research trends and contributions, enabling a thorough examination of the subject matter. By analysing a large body of academic articles, bibliometrics provides insights into publication patterns, citation networks, and the knowledgeable structure of a research arena. Therefore, bibliometric analysis can enhance our understanding of BCT research within the healthcare domain. However, the scarcity of adequate bibliometric studies examining the intersection of BCT and the healthcare industry is apparent. This dearth of review articles utilising bibliometric tools to analyse the developmental trends within the literature presents an opportunity for further research within the academic community.

Therefore, this study aims to delineate the most recent literature within the realm of BCT in the healthcare sector. It contributes to the existing literature by conducting a bibliometrics analysis to map the trends and developments in blockchain research within the healthcare industry. Consequently, the study offers a bibliometric overview of the research outcomes thus far, utilising the Visualization of Similarities (VOS) viewer software to visually represent the extracted bibliographic material [23]. By examining a comprehensive collection of scholarly articles from relevant databases, we seek to identify influential authors, highly cited papers, and emerging research themes. Furthermore, we aim to provide insights into the evolving research landscape and identify gaps that require further exploration.

Understanding the trends and patterns in blockchain research within healthcare can inform stakeholders, policymakers, and researchers about the current state of knowledge and the potential benefits and challenges related to the adoption of BCT. This study aims to contribute valuable insights and offer recommendations for upcoming research directions by synthesising and analysing the existing scholarly discourse.

The upcoming sections of this paper encompass the methodology employed in the bibliometric analysis (section II), the presentation of the analysis and its findings (section III), a detailed discussion of results and future research avenues (section IV), and the ultimate conclusion of the paper (section V).

II. METHODOLOGY

Bibliometric analysis proves more suitable for analysing large-scale literature data from both quantitative and qualitative perspectives [2] [24]. By integrating various disciplines such as mathematics, statistics, and graphics, bibliometric analysis applies data mining, processing, measurement, and mapping techniques. to visually represent internal relationships, including knowledge frameworks, structures, interactions, and crossovers [25], [26].

The wide acceptance and effectiveness of the bibliometric method can be attributed to its ability to comprehensively present the current status of publications, institutions, research areas of interest, and patterns in research themes [24]. This method is a widespread and accurate approach for examining and analysing a large amount of scholarly data. It aims to understand the interconnections among journal citations and summaries the current or emerging situation about a specific

research topic [2]. By reviewing previous studies and considering their progression, bibliometric analysis facilitates the advancement of future research through its indicators [27]. The features mentioned above have fostered the widespread adoption of bibliometric methods in several fields [26], [28]–[31].

This study employed a bibliometric analysis to map the trends and developments in blockchain research within healthcare. In this study, the data was collected from the Scopus database. The Scopus database was selected as it provides a comprehensive collection of scholarly articles from various disciplines and extensively covers healthcare-related literature [2]. Using Scopus, we aimed to include a diverse range of publications contributing to the analysis. The search was conducted on 05 May 2023, with no time constraints. To ensure the relevance of the retrieved articles, a specific search string was constructed using Boolean operators and targeted keywords. The search string used was as follows: TITLE ("Blockchain" AND ("health*" OR "medic*" OR "hospitals" OR "patient")). The search string aimed to identify articles that specifically addressed blockchain technology within the healthcare domain. The asterisk (*) was used as a wildcard to capture variations of the term "health*" and related terms such as "healthcare". The scope of our search was limited to academic articles and conference papers that were written in the English language.

To process the obtained results and gain insights into bibliometric trends, the data was downloaded in CSV format for analysis using the VOS viewer. The popularity of utilising bibliometric maps for easy formation and visualisation is increasing within the field of bibliometric research. This approach enables efficient literature collection and the establishment of interrelationships among selected publications. The VOS viewer software facilitates data mining, mapping, and grouping of articles retrieved from the database [32]. One notable strength of VOS viewer is its ability to dynamically adjust display labels based on the algorithm, making it an excellent tool for visualising co-occurrences [23].

III. DATA ANALYSIS AND FINDINGS

The initial search yielded a total of 1,542 publications related to blockchain in healthcare, including 852 journal articles and 690 conference papers. Table I shows the general search results from the Scopus dataset. The analysis focused on several aspects, including the yearly publications, the leading countries contributing to the literature, the top affiliations, highly cited papers, the most prolific authors and data sources, and emerging research themes.

TABLE I.   SUMMARY OF GENERAL RESULTS

Description	Results
Documents	1542
Publication venues (Sources title)	806
Authors	4391
Authors' Affiliations	268
Countries	117
No of Citations	31066
Author Keywords	2618

A. Timeline of Publications:

The analysis showed consistent growth of publications on blockchain in healthcare over the years. From 2016 to 2023, Scopus documented the annual publication count of scholarly articles on BCT in healthcare, as depicted in Figure 1. The inception of the BCT concept occurred in 2008 [1]. From 2010 onwards, researchers have been investigating the possibilities of BCT outside of the financial domain, leading to its application in various fields, including data management [33]. Research articles explicitly focusing on BCT in healthcare emerged in 2016. Initially, there were only a few publications in 2016 and 2017, with 3 and 14 papers, respectively. The following year, in 2018, there was a further increase to 72 publications, indicating a significant surge in research activity on BCT in healthcare. This trend continued in subsequent years, with 176 publications in 2019, 248 in 2020, and 374 in 2021.

The year 2022 witnessed a substantial leap, with 488 publications, marking a peak in research output on BCT in healthcare. This surge indicates a heightened level of interest and investment in studying the potential applications of BCT in healthcare. The increasing number of publications each year reflects the growing recognition of the potential benefits and challenges associated with BCT in healthcare. Researchers, practitioners, and policymakers are actively exploring how BCT can improve data security, interoperability, privacy, and overall healthcare system efficiency.
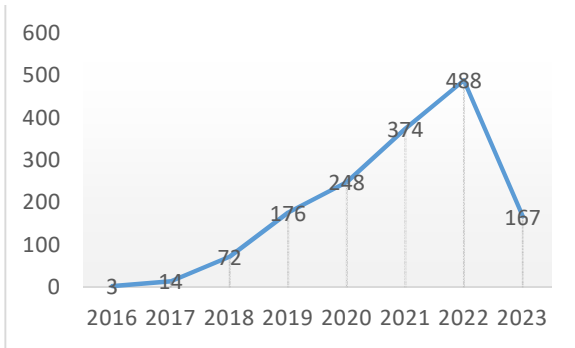

Fig. 1. Publications per year

B. Top Contributing Countries:

Table II presents information regarding the number of publications on BCT in healthcare across the top 10 countries. The papers from these leading nations amount to a total of 1292 publications, which represents 83.2% of the overall number of documents. India leads with a substantial number of 435 publications, indicating a significant research focus on exploring the applications and potential of BCT in the Indian healthcare sector. China closely follows with 319 publications, demonstrating its active involvement and dedication to researching BCT in healthcare. The United States ranks third with 174 publications, reflecting its position as a global leader in technology and healthcare. Other countries contributing to the research in this field include Saudi Arabia with 117 publications, South Korea with 105, the United Kingdom with 82, Pakistan with 60, the United Arab Emirates with 57, Canada with 53, and Malaysia with 51. The data highlights the global interest in

exploring the intersection of blockchain and healthcare, with these countries leading the way regarding research output.

TABLE II. LEADING COUNTRIES

Country	No of documents	Percentage
India	435	28.2%
China	319	20.7%
United States	174	11.3%
Saudi Arabia	117	7.6%
South Korea	105	6.8%
United Kingdom	82	5.3%
Pakistan	60	3.9%
United Arab Emirates	57	28.2%
Canada	53	20.7%
Malaysia	51	11.3%

C. Leading Affiliations:

Table III presents the number of publications on BCT in healthcare by the top 10 affiliations. These affiliations span across several countries and demonstrate a global interest in exploring the applications of BCT in the healthcare sector. "Vellore Institute of Technology" (India) and "Khalifa University of Science and Technology" (UAE) share the top position with 21 publications each. "The Chinese Academy of Sciences" follows closely with 20 publications, showcasing China's commitment to BCT research in the healthcare domain.

Several affiliations, including "Thapar Institute of Engineering & Technology", "University of Electronic Science and Technology of China", "King Saud University", "Xidian University", and "Taif University", all have 16 publications. These affiliations represent both India and China, highlighting the active involvement of researchers from these countries in investigating the applications of BCT in healthcare. Saudi Arabia is also represented by King Saud University and Taif University, demonstrating a growing interest in BCT within the Saudi Arabian healthcare landscape. "SRM Institute of Science and Technology" and "Nirma University, Institute of Technology" from India complete the top 10 list with 15 publications each. These affiliations further emphasise the vibrant research environment in India concerning BCT in healthcare. The active involvement of these affiliations from multiple countries indicates a concerted effort to harness the benefits of BCT and address healthcare challenges globally.

TABLE III. TOP 10 AFFILIATION

Affiliation	Country	No
"Vellore Institute of Technology"	India	21
"Khalifa University of Science and Technology"	UAE	21
"Chinese Academy of Sciences"	China	20
"Thapar Institute of Engineering & Technology"	India	16
"University of Electronic Science and Technology"	China	16
"King Saud University"	Saudi Arabia	16
"Xidian University"	China	16
"Taif University"	Saudi Arabia	16
"SRM Institute of Science and Technology"	India	15
"Nirma University, Institute of Technology"	India	15

D. Prolific Authors:

The analysis identified several prolific authors in the field of BCT in healthcare. At the top of the list is "zhang y." with 17

documents published related to the topic. Following "Zhang Y." are "Jayaraman R.", "Kumar N.", "Kumar R." and "Salah K." who have all published 16 documents each. "Liu Y." and "Tanwar S." have both published 14 documents related to the topic, while "Wang H." and "Zhang I." have published 13 documents each. Finally, "Chen J." has published 12 documents related to the topic. These authors have significantly contributed to the scholarly discourse on BCT in healthcare. Table IV presents the most productive authors in the field of BCT in healthcare.

TABLE IV. MOST PRODUCTIVE AUTHORS

Author Name	No of documents
Zhang Y.	17
Jayaraman R.	16
Kumar N.	16
Kumar R.	16
Salah K.	16
Liu Y.	14
Tanwar S.	14
Wang H.	13
Zhang L.	13
Chen J.	12

E. The Top 10 Papers

Table V presents the analysis of the top 10 papers based on citation count in the field of blockchain-based healthcare. These papers have garnered significant attention and recognition within the academic community, indicating their impact and influence on the progress of BCT in healthcare. The top-cited paper titled "MedRec: Using blockchain for medical data access and permission management" (1374 citations) proposes a decentralised system for managing medical data access and permission via BCT. Other highly cited papers in the table discuss topics such as healthcare data gateways, trust-less medical data sharing, privacy-preserving frameworks for access control and interoperability of electronic health records, and BCT-based systems for remote patient monitoring.

TABLE V. HIGHLY CITED PAPERS

Year	Document Title	Source Title	Citations
2016	"MedRec: Using blockchain for medical data access and permission management" [34]	"Proceedings - 2nd International Conference on Open and Big Data, OBD"	1374
2016	"Healthcare Data Gateways: Found Healthcare Intelligence on Blockchain with Novel Privacy Risk Control" [35]	"Journal of Medical Systems"	803
2017	"MeDShare: Trust-Less Medical Data Sharing among Cloud Service Providers via Blockchain" [36]	"IEEE Access"	692
2016	"Blockchain technology in healthcare: The revolution starts here" [37]	"IEEE 18th International Conference on e-Health Networking, Applications and Services,Healthcom"	665
2018	"Healthcare Blockchain System Using Smart Contracts for Secure Automated Remote Patient Monitoring" [38]	"Journal of Medical Systems"	495
2019	"A decentralised privacy-preserving healthcare blockchain for IoT" [39]	"Sensors (Switzerland)"	474
2018	"Ancile: Privacy-preserving framework for access control and interoperability of electronic health records using blockchain" [40]	"Sustainable Cities and Society"	444
2020	"Blockchain-based electronic healthcare record system for healthcare 4.0 applications" [41]	"Journal of Information Security and Applications"	443
2017	"BBDS: Blockchain-based data sharing for electronic medical records in cloud environments" [42]	"Information (Switzerland)"	369
2018	"Integrating blockchain for data sharing and collaboration in mobile healthcare applications" [43]	"IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC"	360

F. Top Source Titles:

Table VI exhibits the top 10 source titles that have published articles on BCT in healthcare. Among them, "IEEE Access" stood out with 73 documents. The "ACM International Conference Proceeding Series" and "Security and Communication Networks" followed with 49 and 26 documents, respectively. Other notable sources included "Electronics Switzerland" (25 documents) and "Sensors" (25 documents).

TABLE VI. TOP 10 SOURCE TITLES

Source Titles	No of documents
"IEEE Access"	73
"ACM International Conference Proceeding Series"	49
"Security And Communication Networks"	26
"Electronics Switzerland"	25
"Sensors"	25
"Journal Of Medical Internet Research"	22
"Applied Sciences Switzerland"	19
"IEEE Internet Of Things Journal"	16
"Journal Of Healthcare Engineering"	15
"Journal Of Medical Systems"	15

G. Keywords Co-occurrence Analysis

According to Su and Lee [44], the co-occurrence analysis of keywords enables us to discover research themes and analyse the progress of research frontiers within a specific knowledge area. We established a minimum threshold of 30 occurrences for keyword identification when importing Scopus data into VOS Viewer. As a result, a total of 26 keywords were recognised from the 2610 author keywords analysed. The keywords that have similar meanings but different spellings are combined. For example, "blockchain", "blockchain", and "blockchain technology" are combined into "blockchain". Figure 2 illustrates the network of keyword co-occurrences. In this network, each node represents a keyword, and its size is commensurate with the number of publications in which it appears. Furthermore, the width of a line connecting two phrases reflects how frequently they appear together. Table VII shows the words that have at least 30 occurrences. It is important to highlight that this study considered author keywords instead of index keywords.

TABLE VII. CO-OCCURRENCE ANALYSIS OF KEYWORDS

Keyword	Occurrence
Blockchain	1199
Healthcare	286
Security	178
Privacy	140
Smart Contract	226
Ethereum	85

Internet Of Things	154
Electronic Health Records	180
Access Control	62
Data Sharing	53
Covid-19	48
Hyperledger	89
Machine Learning	41
Medical Data	41
Ipfs	39
Authentication	38
Artificial Intelligence	33
Cloud Computing	30
Cryptography	30
Interoperability	30

The analysis of co-occurring keywords in research on BCT in healthcare provides insights into the prominent themes and focus areas in the field. The keywords are clustered based on their co-occurrence patterns, and each cluster represents a distinct topic or research area.

Cluster 1: This cluster includes keywords such as Blockchain, Security, Privacy, Access Control, Data Sharing, Medical Data, Cloud Computing, and Cryptography. It indicates a focus on the fundamental aspects of BCT in healthcare. The keywords Security, Privacy, and Access Control highlight the importance of protecting sensitive healthcare information and controlling access to it [40]. Data Sharing and Medical Data suggest exploring efficient and secure methods for sharing and managing healthcare data within blockchain systems [14]. The inclusion of Cryptography signifies the use of cryptographic techniques to enhance the security and integrity of data stored on the blockchain [45]. Cloud computing may also be investigated as a means to leverage the scalability and storage capabilities of blockchain in healthcare applications [6].

Cluster 2: This cluster encompasses the keywords Blockchain Technology, Internet of Things (IoT), Covid-19, Machine Learning, Artificial Intelligence (AI), and Cloud Computing. It suggests a research focus on the integration of blockchain with emerging technologies and their applications in healthcare [46]. The occurrence of Covid-19 indicates the exploration of BCT solutions in the context of the pandemic,

such as contact tracing or secure health data management [47]. The keywords Machine Learning, AI, and Cloud Computing signify the investigation of how these technologies can be combined with blockchain to enhance healthcare processes, data analysis, and storage. The inclusion of IoT highlights the potential of integrating blockchain and IoT devices for efficient healthcare data exchange and monitoring [39].

Cluster 3: This cluster includes keywords such as Smart Contract, Ethereum, Hyperledger, and Interplanetary File System (Ipfs). It signifies research efforts focused on integrating and utilising smart contracts and blockchain platforms like Ethereum and Hyperledger. This cluster suggests an exploration of the programmability and automation capabilities offered by smart contracts in healthcare applications [48], [49]. Researchers may be investigating how to leverage blockchain frameworks for secure and transparent execution of contracts data storage using Ipfs [50] and exploring the potential of Hyperledger as a platform for blockchain-based healthcare solutions [51].

Cluster 4: This cluster includes keywords such as Electronic Health Records (EHRs) and Interoperability. It highlights research focusing on the interoperability of EHRs using BCT. This cluster suggests efforts to address the challenges associated with exchanging and integrating EHRs across different healthcare systems. Researchers in this cluster may be exploring how blockchain can enable the secure and seamless sharing of patient data while ensuring data integrity and interoperability [5], [51].

Cluster 5: This cluster primarily includes the keywords Healthcare, IoT, and Authentication. It signifies the exploration of blockchain applications in healthcare settings, particularly in the context of IoT devices. The occurrence of Authentication suggests the investigation of secure identity management solutions for IoT devices in healthcare environments [48]. This cluster highlights the potential of blockchain in enhancing healthcare services, patient monitoring, and authentication processes.
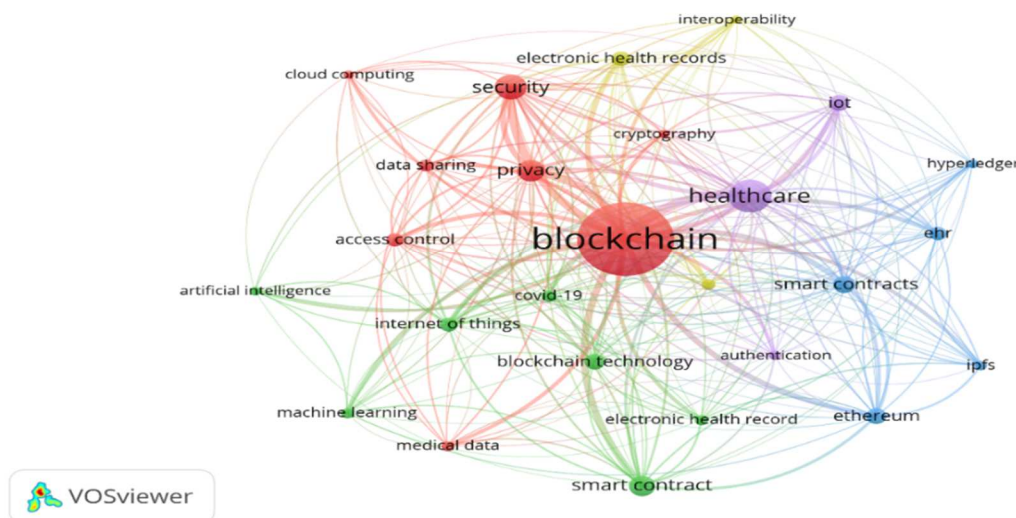

Fig. 2. Keywords co-occurrence Network

The analysis of these clusters provides insights into the diverse research directions in BCT in healthcare. It reveals the focus areas such as data security, integration with emerging technologies, technical implementation, interoperability, and healthcare applications. Understanding these clusters can guide future research and development efforts in leveraging blockchain for improved healthcare outcomes.

IV. Discussion

Examining publications on blockchain in healthcare using bibliometric analysis provides valuable insights into the current status of research, emerging trends, and significant contributors in the field. This discussion section highlights the implications of the findings and explores the broader implications of BCT in the healthcare industry.

The increasing number of publications over the years indicates the growing interest in BCT applications in healthcare. The substantial rise in publications from 2020 to 2022 suggests that researchers are actively exploring the potential of BCT to address the challenges and opportunities in healthcare. This trend signifies the recognition of BCT as a promising solution for enhancing data security, interoperability, and patient privacy in healthcare systems.

India and China have the most publications related to the topic, showcasing their active engagement in BCT research within the healthcare domain. The contributions from these countries reflect their large population, robust technology infrastructure, and growing emphasis on healthcare innovation. The United States also exhibited significant research activity, highlighting the global interest in understanding the impact of BCT on healthcare. The affiliations that contributed the most publications, such as "Vellore Institute of Technology", "Khalifa University of Science and Technology", and "the Chinese Academy of Sciences", demonstrate the dedication of specific institutions to exploring the applications of BCT in healthcare. These affiliations play a pivotal role in advancing the understanding of BCT technology's potential benefits and limitations in healthcare settings.

The analysis of prolific authors reveals individuals who have made substantial contributions to the field of BCT in healthcare. The work of authors "zhang y.", "jayaraman r.", "kumar n.", "kumar r.", and "salah k." underscores their expertise and commitment to advancing research in this domain. Their contributions shed light on various aspects of BCT implementation, including security, privacy, and data exchange in healthcare systems. Top papers in the field of blockchain-based healthcare cover a wide range of topics and have received significant recognition within the academic community. These papers explore the potential of BCT in healthcare, addressing issues such as medical data access, privacy risk control, data sharing, remote patient monitoring, and interoperability of electronic health records. The earliest papers published in 2016 highlight the groundbreaking nature of blockchain in healthcare and set the stage for subsequent research. They emphasise the revolutionary potential of BCT and its ability to improve data security in healthcare settings. Privacy and security are recurring themes in the top papers. Several papers propose novel frameworks and mechanisms for privacy-preserving data sharing, access control, and interoperability of electronic health

records. It reflects the recognition of the sensitive nature of healthcare data and the need for robust privacy measures. The papers also explore specific BCT applications in healthcare, such as remote patient monitoring, healthcare data gateways, and mobile healthcare applications. They demonstrate how blockchain can enhance data exchange, collaboration, and monitoring processes in the healthcare domain.

The prominence of "IEEE Access", the "ACM International Conference Proceeding Series", and other sources in publishing BCT research in healthcare demonstrates the significance of these platforms in disseminating knowledge and fostering scholarly discourse. These sources allow researchers to share their findings, discuss emerging trends, and collaborate on advancing the field.

The keyword co-occurrence analysis reveals several key concepts and themes. These findings shed light on the current research landscape and highlight the significant focus areas within this domain. One of the prominent themes identified in the analysis is the emphasis on data security and privacy. The keywords "data security," "privacy," and "encryption" feature prominently, indicating the growing concern for protecting sensitive healthcare data in BCT applications. The use of encryption algorithms and privacy-preserving techniques, such as attribute-based encryption and proxy re-encryption, is explored to ensure the confidentiality and integrity of patient information. This focus on security and privacy aligns with the need for compliance with regulations like the General Data Protection Regulation (GDPR) and the importance of maintaining trust in healthcare systems. Another major theme that emerges from the analysis is interoperability and data sharing. The keywords "interoperability," "data sharing," and "health information exchange" indicate the effort to enable seamless exchange and integration of health data across different healthcare systems and providers. BCT offers the potential to address the challenges of data interoperability by providing a decentralised and distributed ledger that can facilitate secure and standardised data exchange. Achieving interoperability and enabling efficient data sharing can enhance the quality of healthcare.

The findings of this bibliometric analysis suggest several research themes and directions within the domain of BCT in healthcare. These include BCT-based healthcare data exchange, secure and privacy-preserving clinical trials, BCT-enabled supply chain management in healthcare, and patient consent management using BCT technology. Future research efforts should focus on exploring the practical implementation of BCT in healthcare settings, investigating the ethical implications and regulatory challenges associated with its adoption, and assessing the economic viability and scalability of BCT solutions. Furthermore, further research is needed to overcome challenges and ensure the practical implementation and adoption of BCT solutions in real-world healthcare settings. However, it is important to acknowledge that the adoption of BCT in healthcare is not without challenges. Scalability, regulatory compliance, and the need for long-term evaluation and real-world implementation are areas that require further attention and research [22]. Overcoming these challenges will be crucial in unlocking the full potential of BCT and ensuring its successful integration into healthcare systems.

Based on the analysis of BCT research in healthcare, several future directions can be identified as follows:

1. Enhanced Security and Privacy: Given the importance of security and privacy in healthcare data management, future research can focus on developing advanced encryption techniques, access control mechanisms, and privacy-preserving protocols within blockchain systems. It includes exploring novel cryptographic algorithms, zero-knowledge proofs, and privacy-enhancing technologies to ensure secure and confidential handling of medical data.

2. Integration with Emerging Technologies: As indicated by the keywords related to smart contracts, IoT, AI, and machine learning, future research can explore the integration of BCT with these emerging technologies. This includes investigating how smart contracts can automate and streamline healthcare processes, how IoT devices can securely interact with blockchain systems, and how AI and machine learning can leverage blockchain data for predictive analytics and personalised healthcare.

3. Standardisation and Interoperability: Interoperability remains a crucial challenge in healthcare systems. Future research can focus on developing interoperable standards and frameworks that enable the seamless exchange and integration of EHR across different BCT platforms. This involves exploring the potential of Hyperledger Fabric and other blockchain frameworks to establish interoperable EHR systems while ensuring data integrity and privacy.

4. Real-world Applications and Case Studies: As the adoption of BCT in healthcare continues to grow, there is a need for more real-world applications and case studies. Future research can focus on implementing and evaluating BCT-based solutions in healthcare settings, such as clinical trials, supply chain management, telemedicine, and patient data management. This empirical research can provide insights into the practical challenges, benefits, and limitations of implementing BCT in diverse healthcare contexts.

5. Regulatory and Ethical Considerations: As BCT disrupts traditional healthcare systems, there is a need to address regulatory and ethical considerations. Future research can explore the legal and ethical implications of using BCT in healthcare, such as data ownership, consent management, and compliance with data protection regulations. This includes examining the ethical use of patient data, ensuring transparency, and establishing governance frameworks for blockchain-based healthcare systems.

Overall, the future direction of BCT research in healthcare involves a multidisciplinary approach that combines technical advancements, practical implementations, standardisation efforts, and ethical considerations. By addressing these areas, researchers can contribute to the development of secure, interoperable, and ethically sound blockchain solutions that have the potential to transform the healthcare industry.

V. Conclusion

The research presented in this paper has provided a comprehensive examination of the application of BCT in the healthcare industry. This bibliometric analysis has highlighted the increasing interest in BCT in the healthcare sector. The findings reveal the contributions of various countries, affiliations, authors, and sources to the scholarly discourse on BCT in healthcare. The analysis uncovered that BCT research in healthcare has steadily increased, indicating growing interest in its transformative potential. Research themes, like data security and privacy, reflect pressing concerns for healthcare organisations adopting BCT. BCT holds promise in addressing critical healthcare issues: data security, privacy, interoperability, trust, and convergence with emerging technologies. BCT's features (decentralised storage, cryptographic algorithms, smart contracts, and distributed networks) offer robust solutions for protecting sensitive healthcare data, enabling seamless data exchange, establishing trust, and integrating AI and IoT. The findings also highlight dominant regions and institutions contributing to BCT research, showcasing global expertise. By deepening understanding of the trends and gaps in BCT research in healthcare, this study offers a foundation for future research and policymaking effort guiding stakeholders in leveraging BCT to tackle challenges in healthcare.

While this study provides valuable insights into the current landscape of BCT research in healthcare, it is essential to acknowledge its limitations. The analysis was conducted using the Scopus database and focused on English-language publications, which may introduce biases in terms of geographic representation and language accessibility. Furthermore, the analysis was based solely on quantitative indicators and did not incorporate qualitative assessments of the content and quality of the publications. To build upon this research, future studies should consider incorporating a wider range of data sources, such as patents, conference proceedings, and grey literature. Additionally, qualitative research methods, such as interviews or surveys, can provide valuable insights into the perspectives and experiences of healthcare practitioners, researchers, and policymakers regarding BCT implementation in healthcare settings.

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