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PLATFORM APPROACHES IN HEALTHCARE

ORIGINAL RESEARCH

Blockchain Applications in Core Healthcare Services: Patient Data, Research, and Institutional Processes

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Abstract

Objective: This research aims to systematically examine the application of blockchain technology in core primary healthcare services, with a particular focus on its ability to enhance data integrity, transparency, and operational efficiency. The objective is to identify and analyze the primary areas where blockchain is being utilized within the health sciences and to evaluate its contributions to secure patient consent, reliable data verification, and the protection of sensitive health information.

Methods: This study conducted a systematic literature review of research and review articles indexed in the Web of Science Core Collection between January 10 and March 15, 2025. Articles were selected based on predefined search strings targeting blockchain applications in health sciences, as detailed in the search strategy (Figure 1). Bibliometric analysis was performed using VOSviewer and the Biblioshiny interface of R Bibliometrix to identify thematic areas, keyword co-occurrences, and research trends. Overlay and network visualizations were used to reveal temporal patterns and relational structures among keywords. To enhance the scope of the review, supplementary searches were also conducted via Google Scholar, providing additional insight into emerging topics not yet indexed in Web of Science.

Results: The analysis revealed eight major thematic areas where blockchain is prominently applied: secure patient consent and data management, healthcare supply chain processes, clinical research and monitoring, legal and intellectual property concerns, disease tracking and epidemiological management including COVID-19, insurance and billing systems, organ transplantation logistics, and applications in cancer and pharmaceutical research. The data demonstrate an increasing focus on blockchain's role in enhancing transparency and accountability in both institutional and patient-centered healthcare services.

Conclusions: Blockchain holds considerable promise for advancing healthcare systems. However, its effective implementation depends on a comprehensive approach that combines technological innovation with supportive policy frameworks and ethical considerations. These findings provide valuable guidance for stakeholders seeking to integrate blockchain in health service delivery.

Plain Language Summary

This study explores how blockchain technology is applied across eight core areas of primary health care to enhance data integrity, transparency, and efficiency. A systematic review and bibliometric analysis of articles indexed in the Web of Science (from January to March 2025) was conducted to identify key trends and application domains. The analysis revealed eight major focus areas, including patient data management, clinical research, legal considerations, disease tracking, and pharmaceutical applications. Additional insights were obtained through Google Scholar. The findings suggest that while blockchain holds strong potential for advancing healthcare systems, successful adoption requires supportive policies, ethical frameworks, and coordinated sector-wide efforts.

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Blockchain is driving a significant transformation in health sciences by enabling secure, transparent, and decentralized data management systems. As healthcare systems face persistent challenges such as data breaches, verification issues, and inefficiencies in supply chain management, blockchain emerges as a promising solution. By leveraging distributed ledger systems, it facilitates more reliable, efficient, and accessible healthcare services.

One of the core strengths of blockchain lies in its capacity to enhance the security and interoperability of personal health records. Roehrs et al. highlighted its potential to overcome the limitations of fragmented data by offering a unified and decentralized view of patient information.[1] Various approaches have since been developed to integrate blockchain into healthcare data systems, such as decentralized storage solutions, secure data-sharing frameworks, and privacy-preserving algorithms.[2,3]

Smart contracts, self-executing protocols built on blockchain, offer additional benefits by automating compliance checks, ensuring the authenticity of pharmaceutical products, and streamlining healthcare billing processes.[4] In patient data management, blockchain facilitates secure consent tracking, data verification, and protection of sensitive information through tamper-resistant ledgers.[5,6,7]

In the supply chain domain, blockchain provides real-time tracking of medical products and helps combat the proliferation of counterfeit drugs by ensuring product authenticity and traceability throughout the logistics network.[8,9] In clinical research, it supports the integrity of trial data, protects intellectual property (IP) rights, and ensures the ethical and legal documentation of research processes.[10–12]

During the COVID-19 pandemic, the value of blockchain was further demonstrated in epidemiological monitoring, as it enabled more accurate and verifiable data collection. Fatoum et al. also noted the potential of blockchain for storing living wills and power of attorney documents, which can be critical in end-of-life care scenarios.[13] Furthermore, blockchain-enabled informed consent mechanisms have been proposed as valuable tools for improving transparency and trust among trial sponsors, ethics boards, and patients.

Blockchain is revolutionizing healthcare by enhancing the security, traceability, and transparency of medical data and processes. Its use in insurance verification, pharmaceutical logistics, and clinical trial management is accelerating the shift toward a more digitally resilient and accountable health ecosystem. As the sector continues to digitalize, the need for robust, privacy-preserving, and trustworthy data systems becomes increasingly critical.

This paper aims to examine the core application areas of blockchain in healthcare focusing on patient consent, data security, pharmaceutical supply chains, clinical research, epidemiology, billing systems, and critical disease management. By reviewing current literature and practical implementations, we explore how blockchain addresses longstanding issues in healthcare and assess its potential to shape a future-proof roadmap for the industry.

Key contributions of blockchain in health sciences can be listed as follows:

- Enhances data security and patient privacy through decentralized systems
- Strengthens verification processes and prevents unauthorized access
- Improves supply chain transparency and reduces pharmaceutical counterfeiting
- Ensures data integrity and IP protection in clinical research
- Automates healthcare processes via smart contracts
- Enables secure and transparent data sharing, especially for clinical trials
- Supports outbreak management and reliable public health reporting

Key Challenges and Healthcare Pain Points

Despite advancements in medical technologies and digital health systems, the healthcare sector continues to face a range of persistent challenges that hinder efficiency, trust, and equitable service delivery. Identifying these pain points is essential for understanding the context in which blockchain is being applied:

- *Data Security and Privacy Risks:* Healthcare data breaches remain alarmingly frequent, exposing sensitive patient information to misuse and fraud. Centralized data systems are vulnerable to cyberattacks, unauthorized access, and data manipulation.
- *Fragmented Patient Records:* Health information is often scattered across various institutions and platforms, leading to inconsistencies, incomplete histories, and difficulties in achieving interoperability among providers.
- *Inefficient Consent and Verification Mechanisms:* Managing patient consent, especially across multiple services and stakeholders, is often manual, paper-based, and lacks transparency. This can delay treatments and introduce legal ambiguity.
- *Counterfeit Drugs and Supply Chain Inefficiencies:* The pharmaceutical supply chain struggles with the proliferation of counterfeit medicines, lack of real-time tracking, and poor coordination across distribution networks.
- *Clinical Research Integrity and IP Protection:* Maintaining the accuracy and authenticity of clinical trial data is a critical issue. Furthermore, IP generated from

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medical research is frequently vulnerable to disputes and theft.

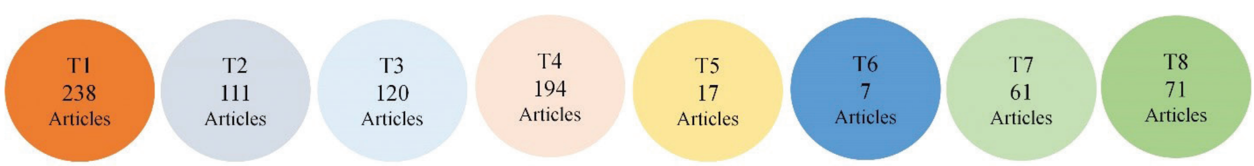
- *Lack of Transparency in Billing and Insurance:* Healthcare billing systems are susceptible to fraud and errors. Patients and providers often lack clear and verifiable documentation of insurance claims and transactions.
- *Data Reliability in Public Health Crises:* During health emergencies like the COVID-19 pandemic, timely and accurate epidemiological data are vital. Traditional systems often fail to provide verifiable, real-time data, leading to delays in response and planning.
- *Organ Transplant Logistics and Ethics:* Organ transplantation involves sensitive logistical coordination and ethical considerations. Centralized tracking systems can be opaque and prone to manipulation or inefficiencies.

These challenges form the foundation for evaluating blockchain's potential role in modern healthcare systems. The subsequent sections of this paper demonstrate how blockchain directly addresses each of these systemic issues through innovative, decentralized solutions.

Methodology

In our study, searches were conducted between January 10, 2025 and March 15, 2025 on research and review articles in the Web of Science database. In the data analysis process, tools such as VOSviewer and R Bibliometrix Biblioshiny were used, especially for the analysis of Web of Science data. Thanks to the relevant tools, prominent research and topics in the field were more easily accessed, and blockchain and blockchain discussions in the health services field were systematically evaluated by researchers. By analyzing research and review articles in the health sciences field related to the subject of blockchain in the Web of Science database, the basic topics and application areas of blockchain in the field were revealed. After conducting preliminary research on the fields related to blockchain and health sciences in the Web of Science, the titles determined in Figure 1 emerged, and the articles were filtered using the search words shown in the figure in order to examine the relevant titles more deeply. Review and research articles were selected and analyzed for filtering, and a comprehensive evaluation was presented for field researchers. Overlay analysis and network analysis performed with the VOSviewer program were used during the evaluation. In this way, temporal analysis (co-occurrence author keywords overlay analysis) and clustering and relational analysis (co-occurrence author keywords network analysis), showing which topics the subjects are related to, could be performed on the keywords used by the researchers in the articles.

In addition, although the Web of Science Core Collection was selected as the primary dataset for our compilation study, additional research was also conducted via Google Scholar. This enabled an in-depth examination of blockchain applications in the health field. In this way, a more comprehensive discussion could be provided for experts in the field. Our study is one of the most comprehensive literature reviews conducted on the subject of blockchain applications, especially in health sciences and health services. This source has provided detailed and in-depth research for professionals in the field.



Topic	Related Health Science Topics	WoS Search Strings for titles and keywords
T1	Patient Consent, Security, Patient Data Verification and Management	("blockchain") and ("patient security" or "patient data" or "patient management" or "electronic health record*" or "health data privacy")
T2	Supply Chain Management Processes	(("blockchain") and (("supply chain" and "health*") or ("supply chain" and "drug*") or ("supply chain" and "medicine*")))
T3	Clinical Research, Research Centers, Monitoring of Research Processes, Legal Aspects, Blockchain Applications for Intellectual Property Management	(("blockchain") and (("clinical research*" or "research center*" or "research data*" or "research process*" or "Legal Aspect*" or "intellectual property"))
T4	Disease Management, Epidemiology and COVID-19 Processes	(("blockchain") and (("Disease Management*" or "Epidemiology" or "COVID-19*"))
T5	Insurance and Healthcare Billing in the Healthcare Sector	(("blockchain") and (("insurance*" and "healthcare") or ("insurance*" and "medicine") or ("insurance*" and "healthcare") or ("investment*" and "healthcare") or ("investment*" and "medicine") or ("investment*" and "healthcare") or ("billing*" and "healthcare") or ("billing*" and "medicine") or ("billing*" and "healthcare")))
T6	Organ Transplantation Processes	(("blockchain") and (("organ transplantation*" or "organ donation*"))
T7	Cancer and Infectious Diseases	(("blockchain") and ("cancer*" or "oncology" or "infectious"))
T8	Pharmacy and Pharmaceutical Sciences Research	(("blockchain") and ("pharmac*" or "pharmaceutical*"))

Fig. 1. Search topics and search strings for blockchain application areas in health sciences.

Findings and Discussion

Our study is one of the most up-to-date and comprehensive bibliometric analyses on the use of blockchain in healthcare. While previous studies in the literature[14–22] have made significant contributions to this field, the difference in this study conducted in 2025 is that it has conducted its analysis directly on articles obtained from a data source such as Web of Science, which indexes the world's most respected and influential academic journals in the field of healthcare sciences.

In this respect, our study goes a significant step beyond the existing literature in terms of both content and scope. Current trends, research areas, and conceptual structures on how blockchain is used in healthcare have been examined in detail within the scope of this analysis.

As detailed in the Methodology section, as a result of the analysis, the ways blockchain is used in healthcare have been clustered under eight headings as given below. Thanks to this structure, the concrete contributions of blockchain to the healthcare system have been evaluated in a holistic manner, and a new perspective has been brought to the literature. These headings are as follows:

- Patient consent, data security, and verification,
- Supply chain management,
- Clinical research and IP,
- Epidemiology and disease management,
- Health insurance and billing,
- Organ transplantation,
- Cancer and infectious disease monitoring, and
- Pharmaceutical and pharmacy research.

As can be seen in Table 1, a structured description of each application area and the specific contributions of blockchain are presented.

In the healthcare sector, blockchain significantly enhances privacy and security by decentralizing patient data storage and reducing the risk of unauthorized access. This decentralized architecture ensures that sensitive patient information remains protected while maintaining data availability across healthcare providers.

In supply chain management, blockchain plays a crucial role in preventing the counterfeiting of pharmaceuticals and medical supplies. By enabling end-to-end traceability, it ensures the authenticity of products and improves transparency throughout procurement and distribution processes.

Clinical research benefits from blockchain through improved data integrity, traceability, and the protection of IP rights. Smart contracts and immutable ledgers support the secure documentation of research activities, which is essential for regulatory compliance and ethical oversight.

During the COVID-19 pandemic, blockchain contributed to public health responses by enhancing the reliability and accuracy of epidemiological data. It enabled real-time data validation and transparent reporting, which were critical for outbreak tracking and resource planning.

Blockchain also strengthens healthcare billing and insurance processes by preventing fraud and improving the verifiability of claims and transactions. The immutable nature of blockchain records supports more efficient and trustworthy financial operations.

In the fields of cancer and infectious disease monitoring, blockchain-based registration systems can improve transparency and facilitate secure data sharing among researchers and institutions. Similarly, in pharmaceutical and pharmacy research, blockchain enhances the ability to track drug development, validate research outputs, and maintain the integrity of data across institutions.

Table 1. Blockchain application areas in health sciences.

Application area	Description	Blockchain contribution/benefit
Patient Consent, Security, Patient Data Verification and Management	Verification of electronic health records, protection of security and privacy	Decentralized data sharing, transparency of approval process, access control
Supply Chain Management Processes	Tracking of medicines, medical devices, and drugs supplies	Anti-counterfeiting, traceability, transparent supply
Clinical Research, Research Centers, Monitoring of Research Processes, Legal Aspects, Blockchain Applications for Intellectual Property Management	Collection and sharing of research data	Data integrity, intellectual property protection, ease of auditing
Disease Management, Epidemiology and COVID-19 Processes	Epidemic monitoring, patient tracking	Instant data sharing, reliable epidemiological data
Insurance and Healthcare Billing in the Healthcare Sector	Service verification and payment processes	Fraud prevention, automated processes
Organ Transplantation Processes	Organ tracking, donor-recipient matching	Transparent recording, secure data transfer, ethical auditing
Cancer and Infectious Diseases	Diagnostic and treatment data management	Treatment traceability, early warning systems
Pharmacy and Pharmaceutical Sciences Research	Drug production and distribution processes	Transparent tracking, counterfeit drug prevention, quality control

Organ transplantation is another critical area where blockchain ensures the traceability of donor and recipient records, streamlines logistics, and supports ethical allocation processes.

Blockchain Applications for Patient Consent, Security, Patient Data Verification, and Management

With the rapid digitalization of healthcare, blockchain has emerged as a powerful tool for enhancing patient safety, data privacy, and transparency. Its decentralized and immutable structure strengthens patient consent processes and enables secure, verifiable management of electronic health records (EHRs). For instance, Wang & Song proposed a blockchain-based health record system integrating attribute-based encryption to ensure confidentiality and access control.[23] Hylock & Zeng emphasized the importance of interoperable, patient-centered systems, highlighting how smart contracts can enable seamless, secure data sharing.[24]

Blockchain allows encrypted storage of medical data, making patient authorization more transparent and traceable.[5] Combined with technologies like AI and data mining, it supports more efficient, evidence-based decision-making.[25] It also reduces medical errors by improving traceability of treatments and verifying provider histories. Figure 2 shows the change in the number of articles obtained on the subjects of Blockchain Applications for Patient Consent, Security, Patient Data Verification, and Management over the years (Figure 2A), cluster analysis (Figure 2B) via authors' keywords.

Studies show high willingness among patients to share clinical data if privacy is ensured.[26] Blockchain's decentralized nature removes reliance on third parties, though technical limitations like scalability and resource use remain challenges.[27] Still, its immutability and interoperability potential make it suitable for sharing data across hospitals, pharmacies, and labs.[28–30]

Researchers have also explored blockchain frameworks to improve digital consent processes, which are increasingly favored by patients for their transparency and trustworthiness.[6,31,32]

In summary, blockchain offers reliable solutions for patient consent, data security, and health information management, which are key pillars for advancing secure, patient-centric healthcare systems. However, although the advantages offered by blockchain in areas such as patient consent, data security, and health information management are promising, there are several challenges in the wide integration of this technology into healthcare systems. Although it provides transparency in data sharing by reducing dependency on third parties, thanks to its decentralized structure, blockchain's technical limitations such as scalability, energy consumption, and transaction delays pose significant obstacles, especially in large healthcare infrastructures. In addition, although it is theoretically possible to provide interoperability in data sharing, standardization between different health information systems is a serious technical and administrative problem. The World Health Organization or health organizations of nations can take more responsibility to resolve such problems. In addition, in the future, the hybrid use of blockchain with approaches such as off-chain storage or federated learning emerges as an important research area in order to balance security and system performance.

Blockchain Applications in Supply Chain Management Processes in the Healthcare Sector

Supply chain management is one of the cornerstones of the global economic structure today. Globalizing markets, increasing competition, and changing consumer demands have made it necessary to establish more efficient, transparent, and reliable systems in supply chains. In this context, blockchain has the potential to transform supply chain processes with its decentralized structure and unchangeable data storage features.[33,34] This has also become true for the healthcare sector. While the healthcare sector attracts attention with its complex supply chain processes and high level of regulatory requirements, it also has difficulties in meeting security, transparency, and efficiency requirements.[35–37]

Figure 3 shows the change in the number of articles on Blockchain Applications in Supply Chain Management Processes in the Healthcare Sector over the years (Figure 3A), cluster analysis (Figure 3B) via authors' keywords.

In the field of health sciences, blockchain application is used extensively in the supply chain management process. It can be used in drug tracking and prevention of counterfeiting, drug manufacturing processes, verification of medical devices, distribution of vaccines or medical supplies during pandemic processes, and food supply processes. Another point that stands out in our research findings is that the topic of food safety in the field of health sciences is also intensively processed in the field: food safety, food distribution, supply chain, and food safety. According to the World Health Organization, 1 in 10 people gets sick from eating contaminated food. The complex food production process and globalization make the food supply chain more sensitive. In recent years, many technologies have been researched to address food insecurity and achieve efficiency in dealing with food recalls.[38] The food supply chain is a complex system that includes many stakeholders such as farmers, manufacturing plants, distributors, retailers, and consumers. Information asymmetry between stakeholders is one of the main factors leading to food fraud.[39] Xu et al. stated that blockchain is a promising technology for food safety control with many ongoing initiatives in food products.[40]

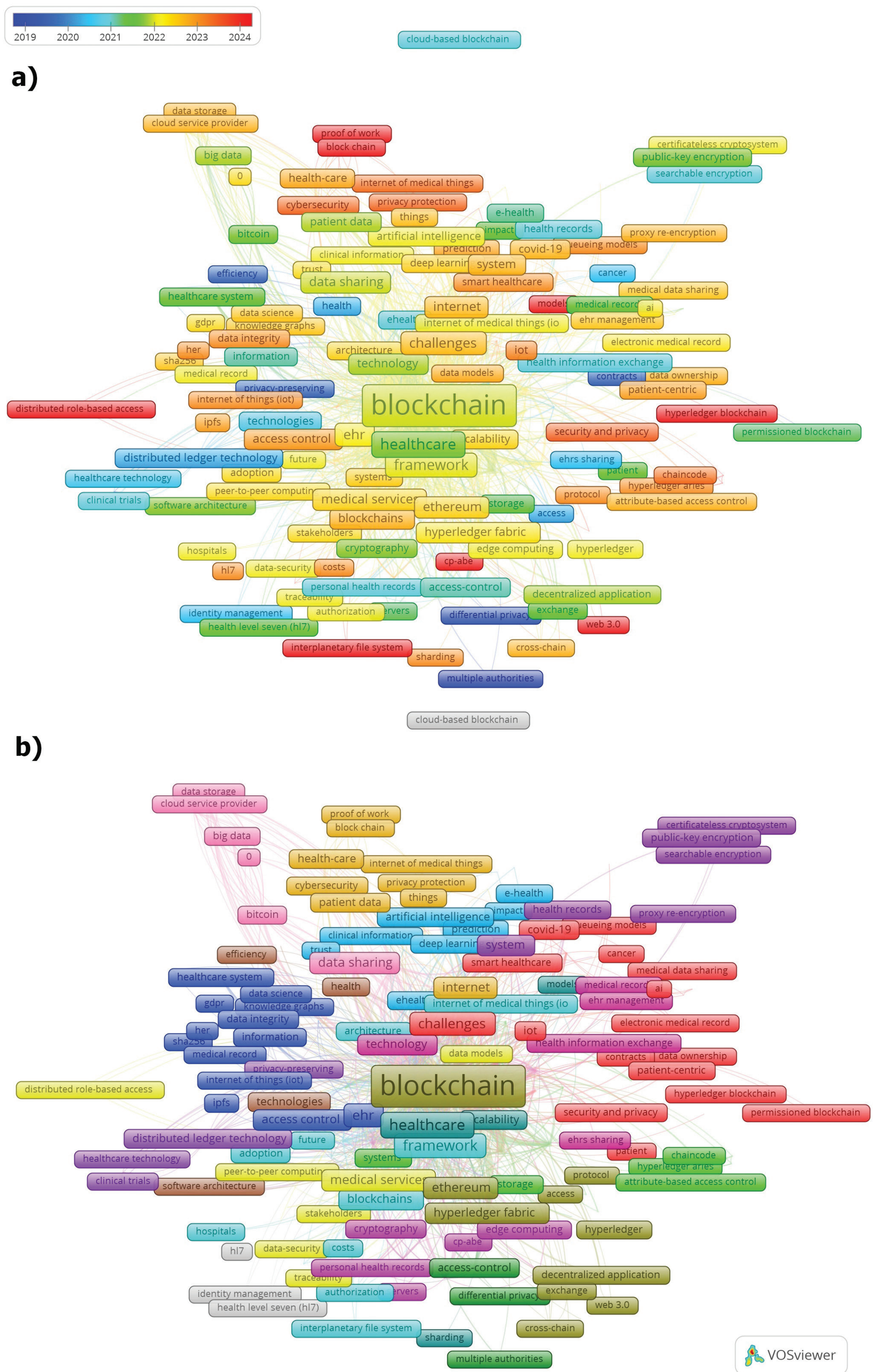


Fig. 2. Articles' network and overlay analyses about blockchain applications for patient consent, security, patient data verification, and management.

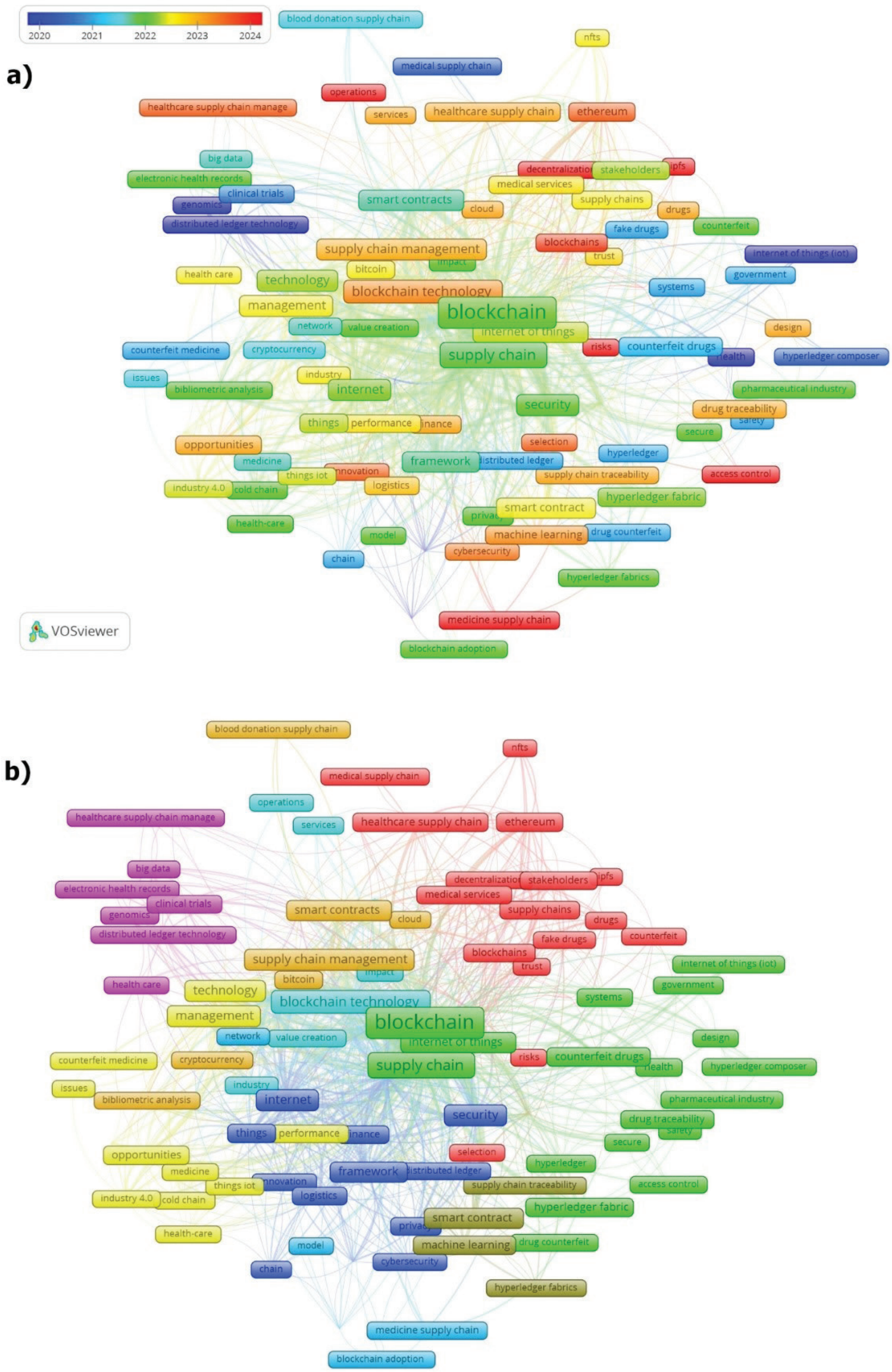


Fig. 3. Articles' network and overlay analyses about blockchain applications in supply chain management processes in the healthcare sector.

Accurate and timely information sharing among many stakeholders in the supply chain of medicines, medical devices, healthcare equipment, and other healthcare products preventing operational disruptions and counterfeiting is of great importance.[41–44] Blockchain has the power to revolutionize the healthcare sector with its potential to increase security, ensure data accuracy, and provide transparency in all processes from food to healthcare equipment supply or pharmaceutical supply processes. Its decentralized structure and unchangeable data recording features can help prevent errors and fraud by ensuring traceability of every step in the supply chain of healthcare products.

The integration of blockchain into supply chain processes in the healthcare sector offers significant opportunities, especially in critical areas such as security, transparency, and traceability. In application areas such as preventing drug counterfeiting, verifying medical devices, and monitoring the distribution of vaccines or medical supplies during pandemics, the unchangeable data records and decentralized structure offered by blockchain significantly increase process security. However, the integration of this technology with complex and highly regulated structures in the healthcare sector presents various technical problems. In particular, issues such as ensuring real-time information sharing between stakeholders, inter-system compatibility, and high transaction costs are still among the main obstacles awaiting solutions. However, for blockchain to be widely adopted in healthcare supply chains, comprehensive transformations are required not only in technology but also in legislation, education, and in-house processes.

Clinical Research, Research Centers, Monitoring of Research Processes, Legal Aspects, and Blockchain Applications for Intellectual Property Management

Clinical research plays a critical role in the development of innovative treatment methods in the field of health and in better understanding diseases. However, these processes bring with them a number of challenges, such as complex management requirements, data security concerns, IP rights, and legal regulations. Research centers must ensure transparency, accuracy, and security when managing clinical research processes. Blockchain offers a potential solution to overcome these challenges.[45,46] Thanks to its decentralized structure and immutable record features, revolutionary applications can be developed in the areas of tracking research data, protecting IP rights, and managing the legal aspects of processes. For example, Li et al. stated that electronic data protection technology that notarizes data should be used to provide legal evidence for medical disputes and medical negligence.[47] Albalwy et al. used a patient forum to determine patients' security and consent concerns in their ConsentChain blockchain application.[48] ConsentChain was developed on the Ethereum platform and used smart contracts to model the actions of patients who can consent or withdraw their data. The relevant system collects and stores patient data and allows for querying and accessing patient data. Sharing rare genetic disease information between genetic databases and laboratories is of critical value, and the developed application supports the sharing of clinical genomic data. Figure 4 shows the change in the articles obtained on the subjects of Clinical Research, Research Centers, Monitoring of Research Processes, Legal Aspects, and Blockchain Applications for Intellectual Property Management over the years (Figure 4A), cluster analysis (Figure 4B) via authors' keywords.

Data, including clinical, research, and publication data, are transmitted and stored in cloud-based networks. These cloud-based systems often lack comprehensiveness, accessibility, interoperability, privacy, accountability, and flexibility, which can lead to delays in medical treatments and slowdowns in research projects and overall inefficiencies. The emergence of blockchain-based technologies offers a reliable solution to ensure that data storage and access are standardized and transparent, independent of a trusted third party. When applied in medical publishing, blockchain can serve to address data sharing and IP issues that medical authors often face.[45]

In clinical trials, data are stored securely and immutably, processes are automated with smart contracts, and participant payments are made correctly. In addition, collaborations based on secure data sharing are developed between researchers. For example, Liang et al. propose a blockchain-based framework to secure IP transactions in the healthcare sector and create social impact.[46]

Drosatos and Kaldoudi stated that blockchain needs to find suitable application paradigms, moving from approaches that discuss storing actual pieces of health data on the blockchain to solutions that use the blockchain primarily as a ledger that stores references to data or data hashes.[49] Hasselgren et al. stated that tracing the origin of health data stored in distributed EHRs will support such data-based medical decision-making and clinical research.[50] Margheri et al. stated that tracing the origin for accessing health data allows patients to have full control over the secondary use of their personal data, that is, creates awareness of where their data go.[51]

Hirano et al. built a system that ensures the security of medical data in a clinical trial using blockchain.[52] They stated that their system can improve clinical trial data management, increase trust in the clinical trial process, and ease regulatory burden. Blockchain is an effective solution for clinical trials, research centers, and monitoring of research and clinical processes, various legal discussions encountered in the health sector, and intellectual property management. Many researchers in the field of

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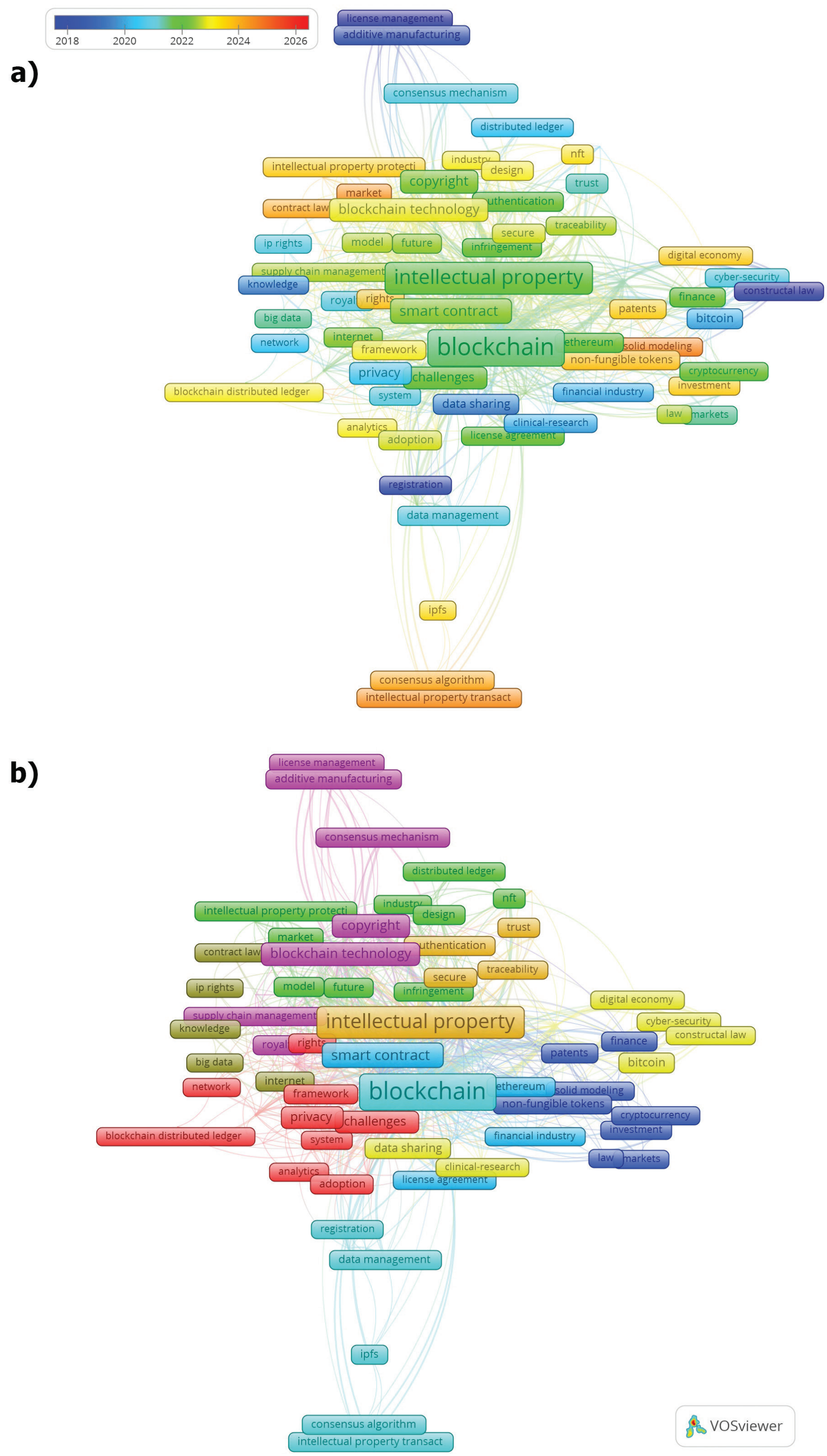

Fig. 4. Articles' network and overlay analyses about clinical research, research centers, monitoring of research processes, legal aspects, and blockchain applications for intellectual property management.

health sciences are working to produce solutions under these topics.

Blockchain Applications in Disease Management, Epidemiology, and COVID-19 Processes

Disease management and epidemiology are key components of efforts to protect and improve public health. The COVID-19 pandemic, in particular, has tested global health systems, while once again revealing the importance of efficient, rapid, and secure delivery of health services and disease management. In this context, this technology can transform health data management with its decentralized structure and secure data storage features. For example, in their study, Jabarulla & Lee stated that public health monitoring enables the analysis of anonymized data to track outbreaks, and they stated that effective interventions can be made by accelerating real-time data sharing in crisis situations, especially pandemics.[53] They stated that thanks to blockchain, users' privacy can be protected in decentralized data sharing, data can be strengthened, reliable data management can be provided during outbreak monitoring, and outbreaks can be combated. Figure 5 shows the change in the number of articles obtained on the subjects of Blockchain Applications in Disease Management, Epidemiology, and COVID-19 Processes over the years (Figure 5A), cluster analysis (Figure 5B) via authors' keywords.

Khurshid presented blockchain as a solution for tracking medical supplies and infected patients.[54] Liu & Liu stated that the construction of a medical resource sharing mechanism under the condition of blockchain in pandemic processes such as COVID-19 can greatly improve the degree of medical resource sharing.[55] In addition, blockchain can be used to increase security and transparency in tracking vaccine vials in pandemic processes such as COVID-19.[56] Smart contracts created and tested with Ethereum can be used to use and protect a digital health passport for test and vaccine participants.[57] Sahal et al. stated that secure real-time data exchange and analysis between multiple participants is important to support efforts against COVID-19, and therefore, a blockchain-based collaborative digital twin framework for decentralized outbreak warnings is important to combat COVID-19 and any future pandemics.[58]

Fusco et al. stated that Blockchain is increasingly being applied to healthcare management as a strategic tool to strengthen operational protocols and create a suitable basis for an effective and efficient evidence-based decision-making process and suggested blockchain application for a safe clinical application against COVID-19.[25] As can be seen, blockchain emerges as a solution especially in times of epidemics when more effective management of diseases is needed, for example, during the COVID-19 process.

Clinical research plays a critical role in developing innovative treatment methods in the healthcare field and in better understanding diseases. However, these processes bring with them a number of challenges such as complex management requirements, data security concerns, IP rights, and legal regulations. Although blockchain presents many challenges in the implementation process, it is a critical and prominent technology that has the potential to overcome these challenges. In particular, blockchain offers significant advantages by providing secure and unchangeable data records in the monitoring of clinical trial data, protection of IP rights, and the management of legal processes. However, in order for this technology to become widespread in the healthcare field, regulatory frameworks must also be harmonized rather than relying solely on technological innovations.

Blockchain Applications for Insurance and Healthcare Billing in the Healthcare Sector

The healthcare sector is a rapidly digitalizing field, and this transformation is leading to significant changes in critical processes such as insurance and healthcare billing. Accuracy, transparency, and security in these processes are of great importance to both patients and healthcare providers. However, problems such as complex billing systems, delays in payment processes, error risks, and fraud are among the main challenges faced by the sector. At this point, Blockchain has the potential to solve these problems with its decentralized structure and secure data recording features. With the verification and reimbursement of traditional healthcare claims, a healthcare provider submits a claim after providing service to a patient, and this claim is later verified and reimbursed by the payer. However, this process leaves out a critical stakeholder, the "patient to whom the services are actually provided." This lack of patient participation poses the risk of fraud and abuse. Blockchain enables secure data management with transparency, which can reduce the risk of healthcare fraud and abuse.[59]

Figure 6 shows the change in the number of articles obtained on the topics of Blockchain Applications for Insurance and Healthcare Billing in the Healthcare Sector over the years (Figure 6A), cluster analysis (Figure 6B) via authors' keywords.

Al-Quayed et al. stated that a large amount of highly sensitive electronic health insurance data are generated every day, which attract fraudulent users.[60] Based on these facts, they proposed an intelligent health insurance fraud detection and prevention framework that leverages cutting-edge capabilities such as blockchain, 5G, cloud, and machine learning to improve the health insurance process. Zhou et al. proposed a blockchain-based threshold medical insurance storage system called MIStore, which is a blockchain-based medical insurance storage system.[61]

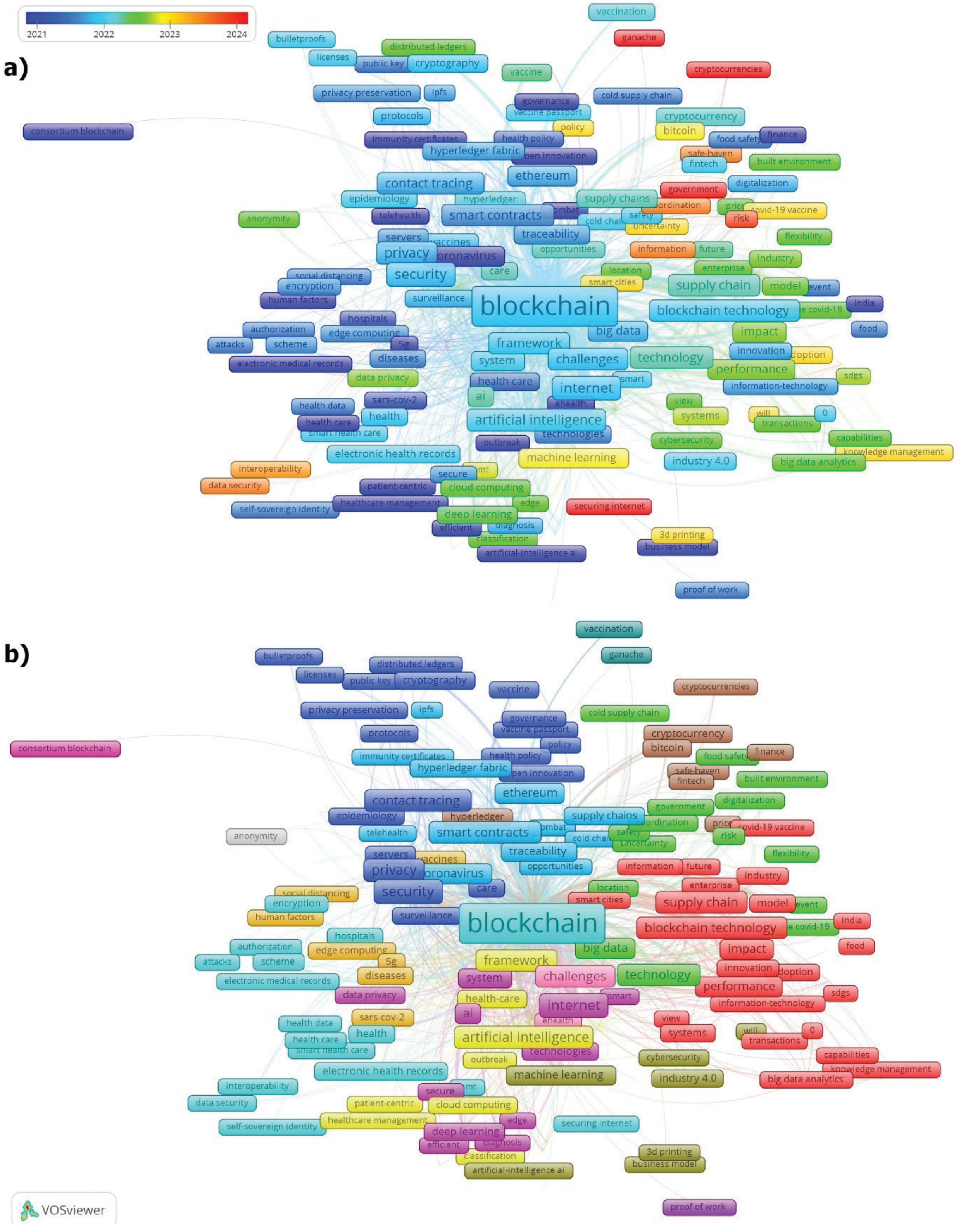

Fig. 5. Articles' network and overlay analyses about blockchain applications in disease management, epidemiology, and COVID-19 processes.

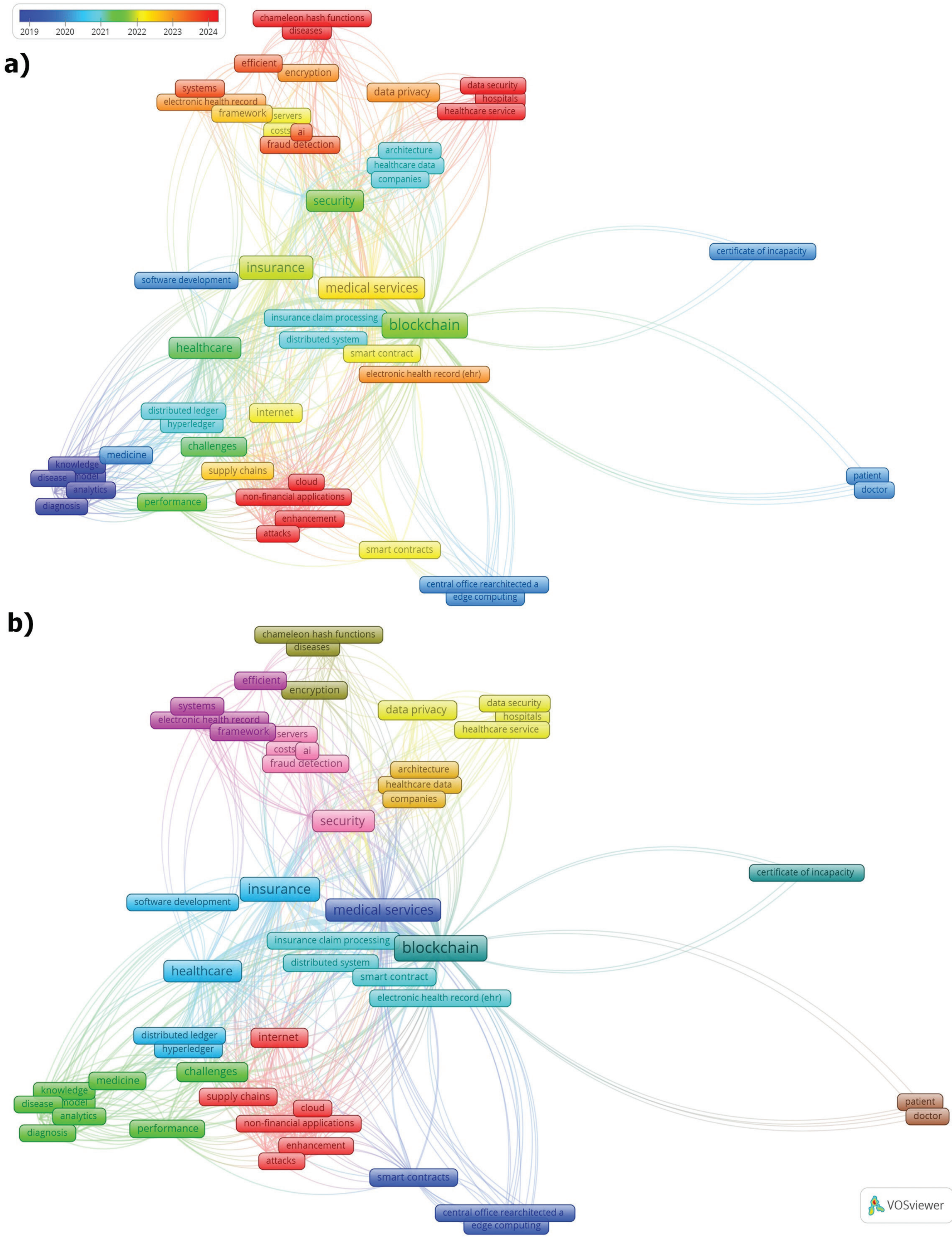

Fig. 6. Articles' network and overlay analyses about blockchain applications for insurance and healthcare billing in the healthcare sector.

They stated that since it is combined with the blockchain, the system gains some special advantages, for example, decentralization, tamper-proof, and registration nodes help users verify publicly verifiable data.

Blockchain enhances transparency and reliability in healthcare insurance systems by offering tamper-proof, decentralized data management. Pandey & Litoriya noted that in India, blockchain enables secure, patient-centered insurance services resistant to fraud and corruption.[62] Xiao et al. introduced HealthChain, a consortium involving hospitals, insurers, and government agencies to manage healthcare billing and claims through a shared blockchain platform.[63]

The key benefits include:

- Tamper-resistance: Ensures data cannot be altered, increasing trust.
- Decentralization: Eliminates third-party intermediaries, allowing direct interactions.
- Confidentiality & Access Control: Patient data are protected using threshold cryptography, enabling secure computations (e.g., spending verification) without exposing raw data.
- Verification: Important data can be publicly verified, improving auditability and reducing processing overhead.[61]

Smart contracts automate claim approvals and payments, significantly reducing fraud, errors, and transaction times in billing processes. While smart contracts' automatic request approvals and payments help reduce errors and fraud in billing processes, questions arise about the exact legal frameworks this technology fits into and the security of patients' data. While the transparency and accessibility provided by blockchain allow patients to maintain control of their data, how these processes will be integrated with international harmonization and standards is also an important area of research.[64] As a result, in order for blockchain-based systems to be used effectively in health insurance and billing processes, not only technological but also legal, ethical, and cultural barriers will need to be overcome.

Blockchain Applications for Organ Transplantation Processes

Organ transplants are hard to manage. They need both medical care and legal steps. Getting organs on time, matching them right, and keeping records clear are all key parts. Technology is helping with this. One useful tool is blockchain. It can track data safely and help avoid errors.[65,66,67,68]

In 2019, Alandjani looked into this. He showed how blockchain can keep transplant data clear and legal. His system used hashed data to match donors and recipients. It also helped with safe data sharing. He said that not all data should go on the blockchain. Instead, only key details should. He also called for more work to improve these systems.[69] Later, in 2022, Hawashin and others designed a better system. They used Ethereum, a type of blockchain, to handle all parts of organ donation. They made six smart contracts to run steps like registering donors and matching them with patients. Their model kept the process open, fair, and private.[70] In 2023, Varshney and his team focused on India. There, organ donation faces many issues such as laws, tech, and ethics. They built a blockchain model with AI help. It automated matches, checked documents, and allowed organ swapping between families. They said strong laws and privacy rules are needed to make it work in India.[71] Another team, Anselmo et al., also in 2023, studied how blockchain helps worldwide. They said it makes waiting lists better and stops illegal trades. Their review said governments and health experts must work together for blockchain to help on a large scale.[72] In 2024, Sitharamulu and others made a new system using private Ethereum. It included six smart contracts. They checked identities and gave access only to trusted people. Their tests showed it made the process safer and more honest. They plan to add more privacy tools later, like Quorum and DApps.[73] Also in 2024, Bawa and his team reviewed many studies. They looked at 85 papers from around the world. They found problems in current systems like trust issues and illegal trading. Blockchain, they said, fixed many of these by making data open and secure. They also talked about using IoT and AI to make the process even better.[74] The most recent work came in 2025 from Haq et al. They built a full blockchain system for transplant tracking. It had six smart contracts and let doctors and drivers record every step. Tests showed it was fast, low-cost, and secure. They plan to add stronger encryption soon.[75]

These studies collectively demonstrate blockchain technology's potential to revolutionize organ transplantation management by enhancing data security, transparency, and operational efficiency. Figure 7 illustrates the growing scholarly interest in blockchain applications for organ transplantation, including publication trends, thematic clusters, and keyword frequencies, highlighting the accelerating momentum of this research area.

Blockchain Applications for Cancer and Infectious Diseases

Cancer and infectious diseases continue to be one of the biggest threats to global health systems. The management of these diseases requires a large data flow and coordination in the early diagnosis, treatment, and disease monitoring processes. However, managing this data accurately, securely, and transparently is critical for the prevention of medical errors and the effectiveness of healthcare services.

Blockchain, with its decentralized structure and unchangeable data recording features, emerges as a solution to these problems in the management of cancer and

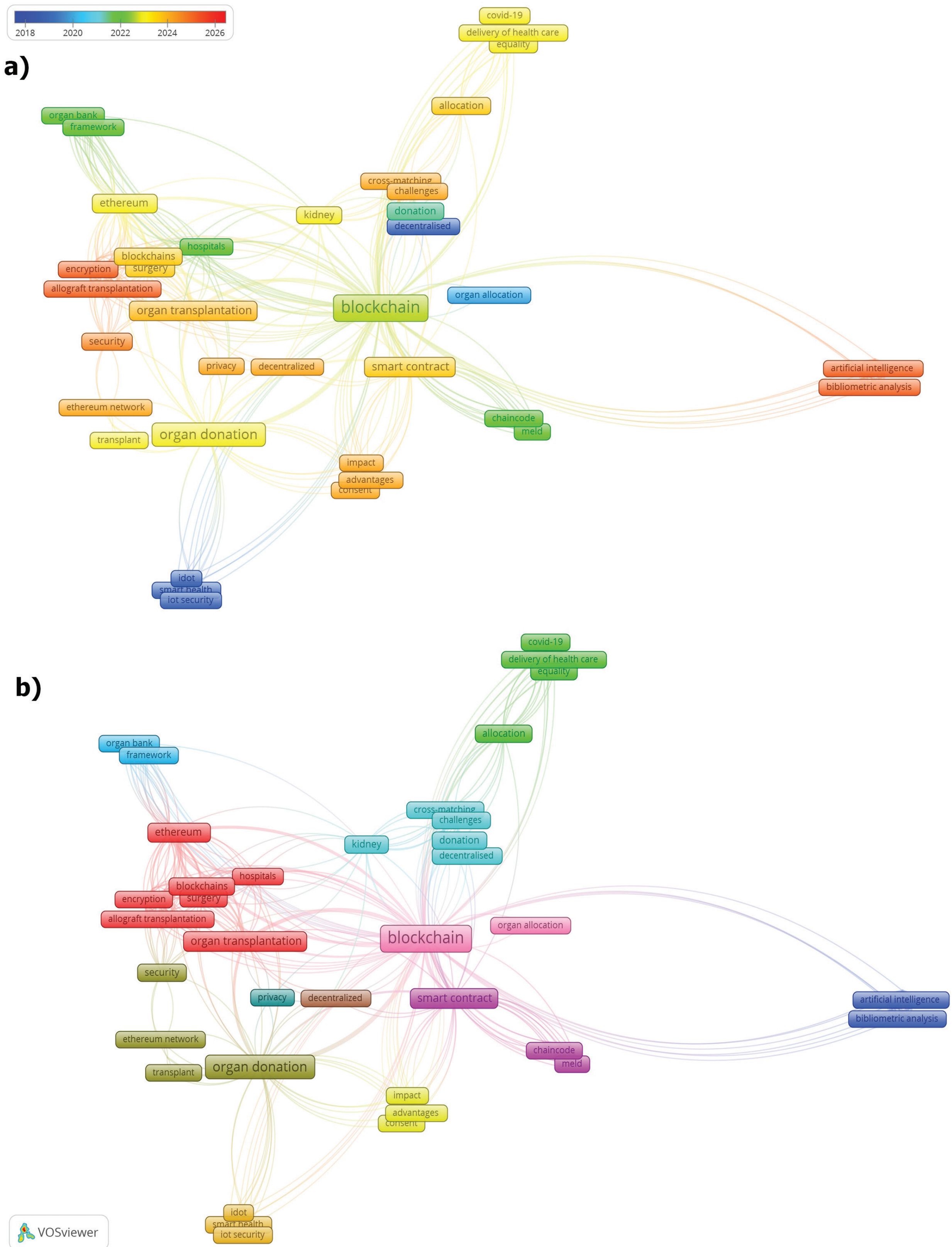

Fig. 7. Articles' network and overlay analyses about blockchain applications for organ transplantation processes.

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infectious diseases. For example, effectively sharing health data generated during standard care can significantly accelerate progress in cancer treatments. At this point, Glicksberg et al. designed and piloted a decentralized, scalable, efficient, economical, and secure strategy for the dissemination of de-identified clinical and genomic data focusing on late-stage cancer.[76] In terms of the overall pilot study, they stated that the Cancer Gene Trust can integrate real-world data of cancer patients more clinically useful and quickly. Figure 8 shows the change in the articles obtained on the topics of Blockchain Applications for Cancer and Infectious Diseases over the years (Figure 8A), cluster analysis (Figure 8B) via authors' keywords.

Dubovitskaya et al. in collaboration with Stony Brook University Hospital developed ACTION-EHR, a system for patient-centric, blockchain-based EHRs data sharing and the management for patient care, particularly radiation therapy for cancer.[77] Their prototype is built on Hyperledger Fabric, an open-source, permissioned blockchain framework.

Tian et al. emphasized the need for more intelligent and efficient infectious disease warning systems, noting that current models face challenges like poor data flow and limited collaboration.[78] To address this, they proposed a blockchain-based early warning framework integrated with AI, big data, and smart contracts.

For tuberculosis, one of the fastest-growing infectious diseases, Srivastava & Srivastava demonstrated how blockchain and machine learning can support early diagnosis and track patient treatment data.[79] Lima et al. suggested using permissioned blockchain networks to store de-identified, semantically annotated data in real-time, enhancing data transparency and reliability.[80]

Zhu et al. proposed a blockchain-based method for tracking infectious diseases by generating a real-time, transparent, and quarriable disease information chain, enabling more effective outbreak monitoring.[81]

In cancer research, combining blockchain with AI and nanotechnology enhances diagnostics, prognosis, and treatment. AI-driven analysis of historical data can improve personalized care, while blockchain ensures secure consent management, data sharing, and timely access to health records critical for both treatment and research.[82] Blockchain is an effective solution as explained in the previous sections.[83] As can be seen, blockchain offers important solutions, especially for cancer patients and infectious diseases, in terms of monitoring diseases, verifying treatment processes, securely sharing patient data, and transparently monitoring treatment results. As partially explained here, it has many benefits, applications, and areas of impact for cancer and infectious diseases.

Blockchain-based systems provide significant benefits, especially in long-term treatment processes such as cancer, in that they can securely manage patients' personal health data and transparently monitor treatment results. Similarly, in infectious diseases, blockchain enables the establishment of early warning systems through faster data flows and more effective collaboration. In addition, when blockchain is integrated with artificial intelligence and nanotechnology in areas such as cancer and infectious diseases, it may be possible to implement more customized and personalized treatment approaches.

Blockchain Applications for Pharmacy and Pharmaceutical Sciences Research

Pharmacy and pharmaceutical sciences have an important place in the field of health and have a complex structure that includes drug development, production, distribution, and patient interaction processes. Data security, transparency, and accuracy play a critical role in patient safety at every stage of these processes. Uddin et al. highlighted that blockchain-based drug traceability can serve as an effective solution for establishing a decentralized and transparent data-sharing platform within the pharmaceutical supply chain. They proposed two blockchain architecture models designed to ensure data immutability, reliability, and accountability. According to their findings, these frameworks offer a strong foundation for health informatics researchers aiming to develop comprehensive, end-to-end traceability systems for the pharmaceutical industry.[84] In another example, Omidian et al. have outlined how blockchain can track, accelerate, and increase the efficiency of incredibly complex operations such as drug development.[85]

Using blockchain to securely share health data with community pharmacies has the potential to improve patient outcomes, optimize medication safety, and strengthen the role of pharmacists in patient care.[86] However, Uddin stated that the increase in online and internet-based pharmacies has made the safety and security of the drug supply chain process more complex and complicated.[87] At this point, Uddin proposed the Medledger system, an innovative tracking and tracing system that utilizes the blockchain-enabled Hyperledger Fabric blockchain platform using smart contracts to prevent drug fraud. In another study, Bali et al. presented a blockchain-based solution for traceability known as PharmaChain in order to make transparent but secure traceability of pharmaceutical drugs faster and more efficient with blockchain in the context of healthcare.[88] In addition, Yu[89] proposed a solution with a blockchain system for innovative IP approach in the drug discovery and development process.

Figure 9 shows the change in the articles obtained on the subjects of Blockchain Applications for Pharmacy and Pharmaceutical Sciences Research over the years (Figure 9A), cluster analysis (Figure 9B) via authors' keywords.

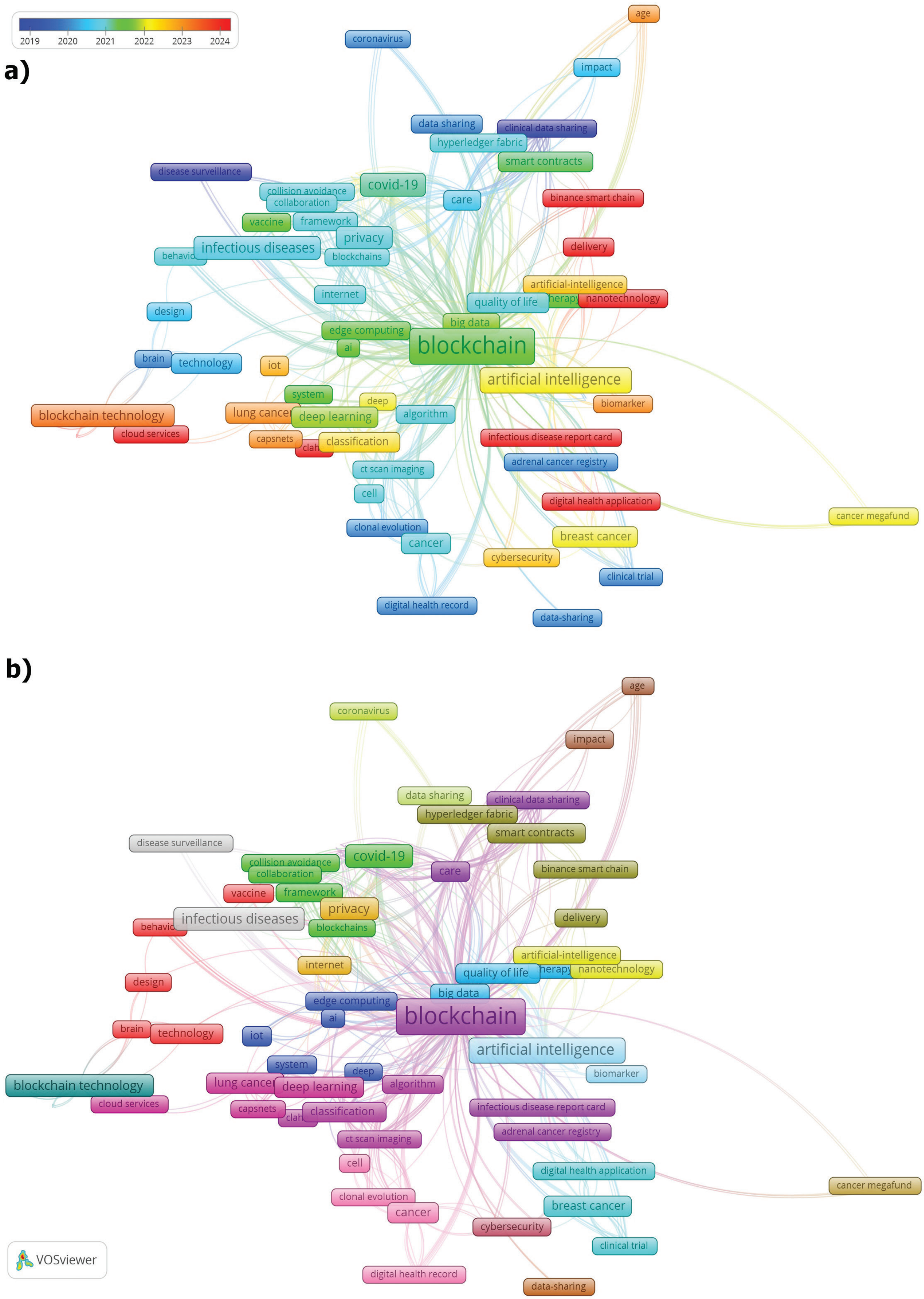

Fig. 8. Articles' network and overlay analyses about blockchain applications for cancer and infectious diseases.

In the study by Agrawal et al., drug recall is identified as a critical issue for manufacturing companies, as manufacturers may face criticism and significant business decline due to a faulty drug.[90] They stated that a faulty drug is a very damaging issue as it can cost several lives, and at this point, they presented the proposed blockchain-supported supply chain management system using Hyperledger Composer, which allows manufacturers to effectively track the drug in the supply chain, providing enhanced security and transparency throughout the process. In their study, Sylim et al. supported information sharing throughout the official drug distribution network in the Philippines with blockchain.[91] They developed and tested a pharmacological surveillance blockchain system. They also stated that the implementation can be more successful with the adoption and sustainability of the technology used and with the strengthening of consumer awareness, strong policy support, and good governance. Alnafrani & Acharya emphasized the need for healthcare providers to access comprehensive, borderless datasets, and improve drug tracking to enhance trust and accountability in the pharmaceutical sector.[92] They proposed a blockchain-based framework for secure and interoperable access to prescription records. Similarly, Tseng et al. introduced the Gcoin blockchain to create transparent drug transaction data, suggesting a shift from traditional inspections to a real-time surveillance model involving all supply chain participants to combat counterfeit drugs and protect public health.[93]

Gaynor et al. evaluated that medicines are not the only thing procured in the health system. A procurement process is required to track the transportation of organs for organ transplantation, and they stated that blockchain can be used at this point.[94] For example, blockchain is seen as a solution for preoperative evaluation of deceased donors, transnational cross-programs with international waiting list databases, and reducing black market donations.[72] As can be seen, blockchain, thanks to its decentralized structure, transparency, and unchangeable record features, can increase the traceability of drugs, prevent counterfeiting, and contribute to the provision of more effective and secure health care by providing secure data sharing in organ transplantation processes.

Blockchain offers significant opportunities in terms of data security, transparency, and traceability in the pharmaceutical supply chain and organ transplantation processes. Accurate and reliable data management is of critical importance, especially in drug development, production, distribution, and patient interaction processes. Blockchain can be an effective tool to prevent fraud and reduce errors in processes by making each stage traceable and unchangeable. However, as mentioned before, in order for blockchain to be fully implemented in supply chain processes, data standardization and compatibility must be ensured among large-scale healthcare systems. As a result, it has been seen that more research is required for blockchain to create a significant transformation in the healthcare sector, and more application projects and field experience must be transferred. In addition, acting in harmony with health authorities is also of critical importance.

Conclusion and Recommendation

Blockchain has the potential for a multidimensional and comprehensive transformation in health sciences, both technically and in terms of governance. The evaluations in the eight application areas of blockchain discussed in this article reveal the significant contributions of blockchain in improving data security, transparency, traceability, and patient-centered service delivery. It has been emphasized that blockchain solutions are becoming increasingly prominent, from patient approval processes to supply chain management, clinical research, and digital health applications. If we recall the main findings of the article, we can list them as follows:

- Data Security and Privacy: Blockchain technical features allow for data security and privacy. It also eliminates the need to trust a center since it does not need to be controlled by a center. In other words, decentralized data storage through Blockchain strengthens patient privacy by protecting against data breaches.
- Transparency and Traceability: Transparency of processes and technical infrastructure is an important issue. Blockchain provides this infrastructure. All processes and transactions are recorded, and immutability is guaranteed. For example, verifiable processes in supply chains and billing systems help prevent fraud and increase stakeholder trust.
- Collaboration and Integration: Blockchain has the potential to integrate with many emerging technologies. For example, it facilitates secure data sharing and integration with AI, IoT, and genomics, paving the way for personalized healthcare.
- Global and Crisis-Focused Applications: Blockchain-based applications have the potential to contribute to better and faster execution of processes in global health crises such as the COVID-19 process. Real-time data exchange and reliable outbreak management are the features that reveal the role of blockchain in resilient health systems.
- Compatibility with Emerging Technologies: Being able to easily and fully integrate with new technologies is critical to the sustainability of the health information systems and infrastructures. The integration of Blockchain with AR, IoT, VR, Metaverse, and Health 5.0 is important for the digital transformation of health services and a sustainable and up-to-date health information system infrastructure.

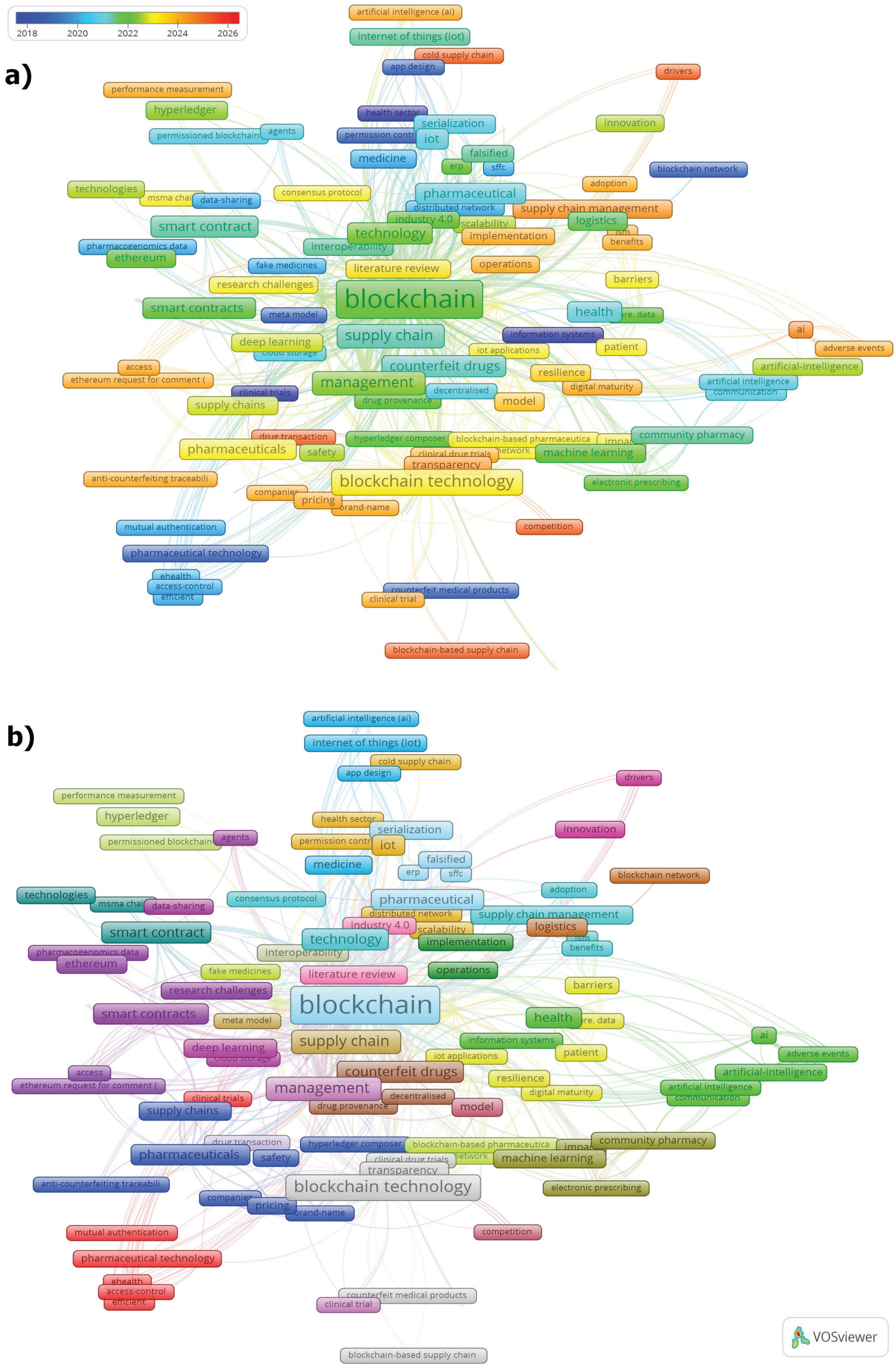

Fig. 9. Articles' network and overlay analyses about blockchain applications for pharmacy and pharmaceutical sciences research.

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In the light of these findings, we can make the following suggestions based on the results and evaluations obtained from the study:

- Technical Infrastructure Development: Healthcare providers should implement blockchain-based systems and integrate them with the existing Information Technology infrastructure. The infrastructure integration process should be carried out meticulously and in accordance with international standards. Integration processes should be considered in a multifaceted manner, basic needs specific to the healthcare field should be considered, and a sustainable investment plan should be made for the system infrastructure for today and the future. Both technical and financial planning should be made in detail in terms of system sustainability. Continuous revision or re-establishment of infrastructures to be established in healthcare systems is a process that is both risky and has financial and human costs. Therefore, it is essential that the infrastructure to be established is created by taking these situations into consideration.
- Education and Awareness: Training programs should be developed for professionals, and blockchain-related courses should be included in the health sciences curriculum. The content detailed in this article and more can be added to secondary and higher education curricula that provide health education. In order to use and disseminate the established system, cooperation can be established with educational institutions, and demo application environments can be established and used while students are still students. Similarly, in-house training processes can be used to learn these systems, increase their usage rate, and ensure that current users are more professional and can use all functions correctly.
- Regulatory and Policy Frameworks: Clear and adaptable legal frameworks should be created to support the adoption of blockchain in healthcare services, including privacy and IP laws. Legal regulations have been made and continue to be made in the world, Europe and Turkey on data protection, data security, and privacy. In the healthcare field, studies should be carried out with the comprehensive participation of relevant parties to create laws, regulations, and related legislation and to revise them according to current needs.
- Research and Innovation Support: Interdisciplinary research and public-private sector and university partnerships should be encouraged to pilot innovative blockchain applications. Research potential should be increased with various project calls, postdoctoral research opportunities to be opened in universities, and doctoral and graduate programs. It would be appropriate to carry out these projects and studies together with the private sector, to minimize integration problems between the private sector and the public, and to continue the process with mutual interaction. Various public and private incentives should be planned to encourage companies or individuals who can conduct research and development on this subject.
- Ethical and Social Issues: Awareness should be increased about ethical blockchain use, and inclusive systems should be designed for vulnerable and digitally underserved communities and groups. In this regard, first of all, efforts should be made to inform people, explain the technical details of blockchain security and privacy, and to accept how its use is carried out ethically and socially. This can only be achieved by educating people and introducing these technologies at all levels and environments.

In conclusion, blockchain offers groundbreaking opportunities in various areas of health sciences. However, realizing this potential requires a holistic approach that includes technological advances, policy reform, and ethical safeguards. In the future of health systems, blockchain should not be seen as a mere tool but as the cornerstone of trust, collaboration, transparency, and privacy.

Limitations

While this study provides a comprehensive evaluation of blockchain applications in healthcare, several limitations should be acknowledged. First, the research primarily relied on data from the Web of Science Core Collection, which may have excluded relevant studies indexed in other databases or published in non-English languages. Although supplementary searches were conducted via Google Scholar, the inclusion of grey literature was limited. Second, the bibliometric analysis focused on published academic research and may not fully capture recent industry innovations or pilot programs that still in development. Finally, the scope of the review was confined to eight major thematic areas identified during the analysis, which, while significant, may not represent all emerging applications or regional implementations of blockchain in health systems.

Future Work

Given the limitations identified in this study, future research should address several critical gaps to provide a more complete understanding of blockchain's role in healthcare. First, future reviews should expand the scope of data sources beyond the Web of Science Core Collection to include additional academic databases such as Scopus, PubMed, and IEEE Xplore, as well as regional repositories and non-English language publications. This would help capture a more diverse and globally representative body of literature. Additionally, increased inclusion of grey literature, policy papers, and technical reports would offer valuable insights into industry-driven innovations and real-world pilot implementations that are often absent from academic discourse.

Future research should focus on enhancing the scalability, interoperability, and regulatory alignment of blockchain solutions in healthcare. Key areas include developing integration frameworks with existing health IT systems, creating lightweight and energy-efficient consensus mechanisms, and addressing legal and ethical considerations around data ownership and cross-border sharing. Usability studies and real-world pilot programs are also needed to assess long-term effectiveness and adoption. Additionally, exploring synergies between blockchain and emerging technologies, such as AI, could unlock new capabilities in secure, data-driven healthcare delivery.

For blockchain to be utilized sustainably in clinical research and the healthcare sector in the future, interdisciplinary studies, pilot projects, and large-scale field tests are of great importance. In summary, future interdisciplinary research and industry-based pilot projects will play a key role in determining concrete steps that will support the sustainable and effective integration of this technology.

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Conflicts of Interest

None

Contributors

Associate Professor Muhammet Damar, PhD: Conceptualization, methodology, validation, formal analysis, data curation, writing—original draft, writing—review & editing.

Associate Professor Ömer Aydın, PhD: Conceptualization, validation, investigation, writing—review & editing, supervision.

Associate Professor Fatih Safa Erenay, PhD: Conceptualization, investigation, writing—review & editing, supervision.

Data Availability Statement (DAS), Data Sharing, Reproducibility, and Data Repositories

The data that support the findings of this study are available from the corresponding author upon reasonable request. Also, we retrieve our bibliometric data from WoS Core Collection Database, and this database is open for everyone.

Application of AI-Generated Text or Related Technology

No AI tools were used for content creation in this manuscript (e.g., drafting, rewriting, or generating ideas).

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