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Article

Understanding how healthcare innovation is shaped by 5G technology: A comprehensive systematic review

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Abstract: 5G technology is transforming healthcare by enhancing precision, efficiency, and connectivity in diagnostics, treatments, and remote monitoring. Its integration with AI and IoT is set to revolutionize healthcare standards. This study aims to establish the state of the art in research on 5G technology and its impact on healthcare innovation. A systematic review of 79 papers from digital libraries such as IEEE Xplore, Scopus, Springer, ScienceDirect, and ResearchGate was conducted, covering publications from 2018 to 2024. Among the reviewed papers, China and India emerge as leaders in 5G health-related publications. Scopus, Springer Link, and IEEE Xplore house the majority of first-quartile (Q1) papers, whereas Science Direct and other sources show a higher proportion in the second quartile (Q2) and lower rankings. The predominance of Q1 papers in Scopus, Springer Link, and IEEE Xplore underscores these platforms' influence and recognition, reflecting significant advancements in both practice and theory, and highlighting the expanding application of 5G technology in healthcare.

Keywords: 5G technology; healthcare; telemedicine; 5G; digital health; systematic review

1. Introduction

5G technology is transforming the healthcare sector, enabling significant advancements in diagnostics, treatments, and remote monitoring. Its high speeds and reliable connectivity drive innovations that improve the precision and efficiency of healthcare services. These improvements not only increase access and quality of care but also optimize resource management in medical settings. The integration of 5G with emerging technologies such as artificial intelligence (AI) and the Internet of Things (IoT) holds the potential to redefine healthcare standards in the near future. The shift towards a patient-centered approach has accelerated with advances in technologies like 5G and IoT, which enhance coverage, performance, and security in health networks, addressing the complexity of smart applications in this sector (Ahad et al., 2019; Ahmed et al., 2020). In this context, the "hospital of the future" and its connectivity requirements are driving proposals for hybrid optical-radio networks that improve spectral efficiency and reliability in hospital environments, addressing challenges such as spectrum congestion and enhancing communication security (Ahmed et al., 2020; AlQahtani, 2023).

With the digitization of healthcare, significant cybersecurity challenges arise, which are addressed through innovative solutions that combine blockchain, AI, and 5G. For example, the SHINFDP framework uses blockchain and machine learning for health insurance fraud detection, enhancing data security and reliability (Al-Quayed et al., 2023; Pi-Yun et al., 2024). This framework highlights 5G's capability to strengthen the protection of biomedical data, as demonstrated by advanced encryption protocols applied in the Internet of Medical Things and Health Technology (IoMTS) (Chamola et al., 2023; Pi-Yun et al., 2024).

Additionally, the health sector is adopting IoT architectures combined with fog and cloud computing for efficient resource management and improved quality of service in e-Health. An IoT-fog-cloud infrastructure allows up to a 33% reduction in energy consumption through swarm intelligence algorithms, optimizing real-time data communication and reducing operational costs (Ali et al., 2023; AlQahtani, 2023). Similarly, the integration of 5G with AI enables the implementation of monitoring systems in smart homes, where deep learning and wireless detection can classify activities with high accuracy, promoting home health monitoring (Ashleibta et al., 2021; Chamola et al., 2023).

5G connectivity empowers advanced applications in telemedicine, such as telesurgery and remote ultrasound, providing high-quality and stable imaging without compromising the patient's vital signs. These applications demonstrate how technology can expand healthcare coverage in rural and remote areas, optimizing medical infrastructure (Duan et al., 2021; Jabbar et al., 2023). In this same context, the FCC has played a crucial role in spectrum regulation and emergency response, such as during COVID-19, helping bridge the digital divide and supporting accessible health services for vulnerable sectors (Baker et al., 2020; Bhat et al., 2023).

In terms of medical diagnostics, the fusion of AI with 5G in hospital environments has enabled significant advancements. In oncology and diabetic retinopathy detection, hybrid models like CNN-SVD outperform traditional methods, achieving 99.89% accuracy in early diagnosis and improving clinical decision-making (Bilal et al., 2023; Cardoso et al., 2024; Chkioua et al., 2021). Studies indicate that AI is essential for the precision and effectiveness of these systems, and they further highlight international research collaboration, led by the United States and China, in high-impact journal publications (Gamboa-Cruzado et al., 2022; Villavicencio et al., 2024).

Moreover, the combination of technologies such as chatbots and artificial intelligence also influences the customer service experience in healthcare. Chatbots, in particular, have been adapted to improve service interaction and efficiency, while the use of blockchain ensures the secure and encrypted handling of medical records. This convergence facilitates a more secure and optimized administration within patient care systems (Gamboa-Cruzado et al., 2022, 2024; Oncebay-López et al., 2023).

Finally, recent studies on 5G network segmentation for health applications utilize approaches like SDN and NFV to meet quality-of-service requirements and enable softwarization. This segmentation facilitates network management in complex environments, while industry initiatives and standardization efforts show how challenges can be overcome to improve health service operability and quality (Barakabitze et al., 2020; Bhat et al., 2023).

Despite considerable progress in the adoption of disruptive technologies such as 5G, AI, and blockchain in healthcare and other areas, a gap remains in the literature regarding the effective integration of these technologies into practical and scalable solutions. This gap underscores the need for more integrated and systematic studies to address current challenges and maximize the benefits of these emerging innovations. The purpose of this systematic review is to analyze and synthesize the existing literature on the implementation and impact of 5G technologies across various sectors, with a particular focus on healthcare. The paper organizes the systematic review as follows: Section 2 covers methods and materials; Section 3 presents results and discussions; Section 4 outlines conclusions; and finally, Section 5 details limitations and recommendations for future research.

1.1. 5G technology

5G technology, as an evolution of the current 4G network, promises to offer high data speeds, low latency, and massive connectivity, being key for applications such as virtual reality, IoT, and advanced financial systems (Ahad et al., 2019; Ali et al., 2023; Bhat et al., 2023). This advanced system provides low latency and high bandwidth capacity, supporting IoT applications in medical devices, sensors, and wearables, while facilitating the rapid and reliable collection of data for automated diagnostics via machine learning (Ahmed et al., 2020; I-Hsien et al., 2023).

1.2. Healthcare innovation

Innovation in healthcare uses smart devices and advanced networks to manage medical data, optimizing access to accurate information for both doctors and patients, and reducing errors and costs (Ahad et al., 2019). Telemedicine, which originated in the 1950s, is now a vital tool, especially in emergencies and rural areas with limited medical access, supported by associations such as APA and ATA (Hameed et al., 2021). In a 5G-driven environment, where users rely on specialized servers to provide health services, cybersecurity becomes crucial to protect the transmission of sensitive health information over public networks (Tuan-Vinh and Chien-Lung, 2021; Tzu-Wei and Chien-Lung, 2021). Implementing security measures is essential to ensure data availability and confidentiality, thus preventing potential risks to patients (I-Hsien et al., 2023).

2. Materials and methods

A systematic literature review (SLR) approach was used to conduct this research, following the guidelines of Kitchenham et al. (2013) (See **Figure 1**). This method ensures a comprehensive and structured assessment of the topic, allowing for a rigorous and in-depth analysis of the available sources.

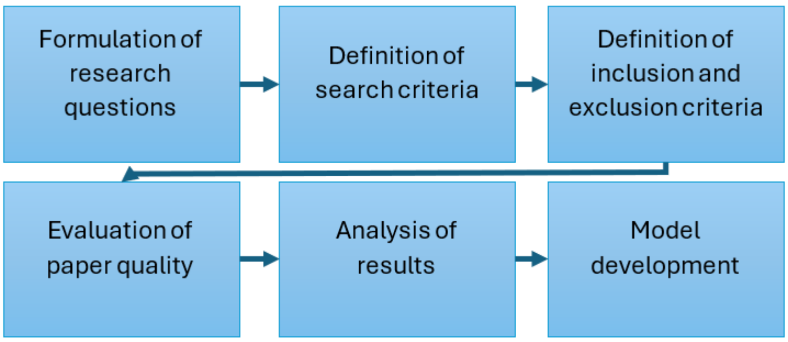

Figure 1. Stages of the SLR.

2.1. Research questions

Formulating research questions (RQ) is crucial in this process; in this context, five key research questions have been defined:

RQ1: What criteria are applied to assess the effectiveness of 5G Technology?

RQ2: What quartile levels are the journals that have published studies on the impact of 5G Technology in healthcare innovation?

RQ3: What conceptualizations have been adopted to define 5G Technology?

RQ4: What are the most frequently used and prominent keywords based on the number of publications in research related to 5G Technology and its influence on healthcare innovation?

RQ5: What are the main thematic categories related to 5G Technology and its impact on healthcare innovation?

2.2. Information sources and search strategies

The databases used for the search of research papers include Scopus, IEEE Xplore, ResearchGate, Springer, and ScienceDirect. The search method was developed using a set of specific terms to optimize information gathering and analysis. As shown in **Table 1**, these search equations were tailored to each information source used.

Table 1. Information sources and search equations.

Source	Search Equation	No. of Documents
ResearchGate	(“5g technology” OR “5g network” OR “5g communication”) AND (“telemedicine” OR “healthcare” OR “e-health”)	1010
Scopus	(TITLE-ABS-KEY(“5g technology” OR “5g network” OR “5g communication” OR “5g wireless” OR “5g” OR “fifth generation technology” OR “fifth generation network” OR “5g connectivity”) AND TITLE-ABS-KEY(“telemedicine” OR “healthcare innovation” OR “healthcare improvement” OR “health innovation” OR “medical innovation” OR “healthcare advancement” OR “healthcare” OR “medical care” OR “healthcare delivery” OR “telehealth” OR “e-health” OR “digital health” OR “remote health” OR “healthcare development” OR “healthcare progress” OR “healthcare enhancement” OR “healthcare transformation” OR “healthcare reform” OR “healthcare modernization” OR “healthcare technology” OR “medical improvement” OR “medical progress” OR “medical development”))	1648
IEEE Xplore	((“5g technology” OR “5g” OR “5g network” OR “5g communication” OR “5g wireless” OR “fifth generation technology”) AND (“telemedicine” OR “healthcare innovation” OR “healthcare improvement” OR “health innovation” OR “medical innovation” OR “healthcare advancement” OR “healthcare” OR “medical care”))	811
Springer	(“5g technology” OR “5g network” OR “5g communication” OR “5g wireless” OR “5g” OR “fifth generation technology” OR “fifth generation network” OR “5g connectivity”) AND (“telemedicine” OR “healthcare innovation” OR “healthcare improvement” OR “health innovation” OR “medical innovation” OR “healthcare advancement” OR “healthcare” OR “medical care” OR “healthcare delivery” OR “telehealth” OR “e-health” OR “digital health” OR “remote health” OR “healthcare development” OR “healthcare progress” OR “healthcare enhancement” OR “healthcare transformation” OR “healthcare reform” OR “healthcare modernization” OR “healthcare technology” OR “medical improvement” OR “medical progress” OR “medical development”)	1000
ScienceDirect	(“5g technology” OR “5g network” OR “5g communication”) AND (“telemedicine” OR “digital health” OR “healthcare delivery” OR “e-health” OR “medical innovation”)	695
Total		5164

As observed, a total of 5164 documents were gathered upon completing the search across each information source.

2.3. Study selection

In the initial phase, 5164 documents were collected using keywords relevant to the study. Various exclusion criteria (EC) were applied to select high-quality papers. After the selection process, 79 papers were chosen, as illustrated in **Figure 2**.

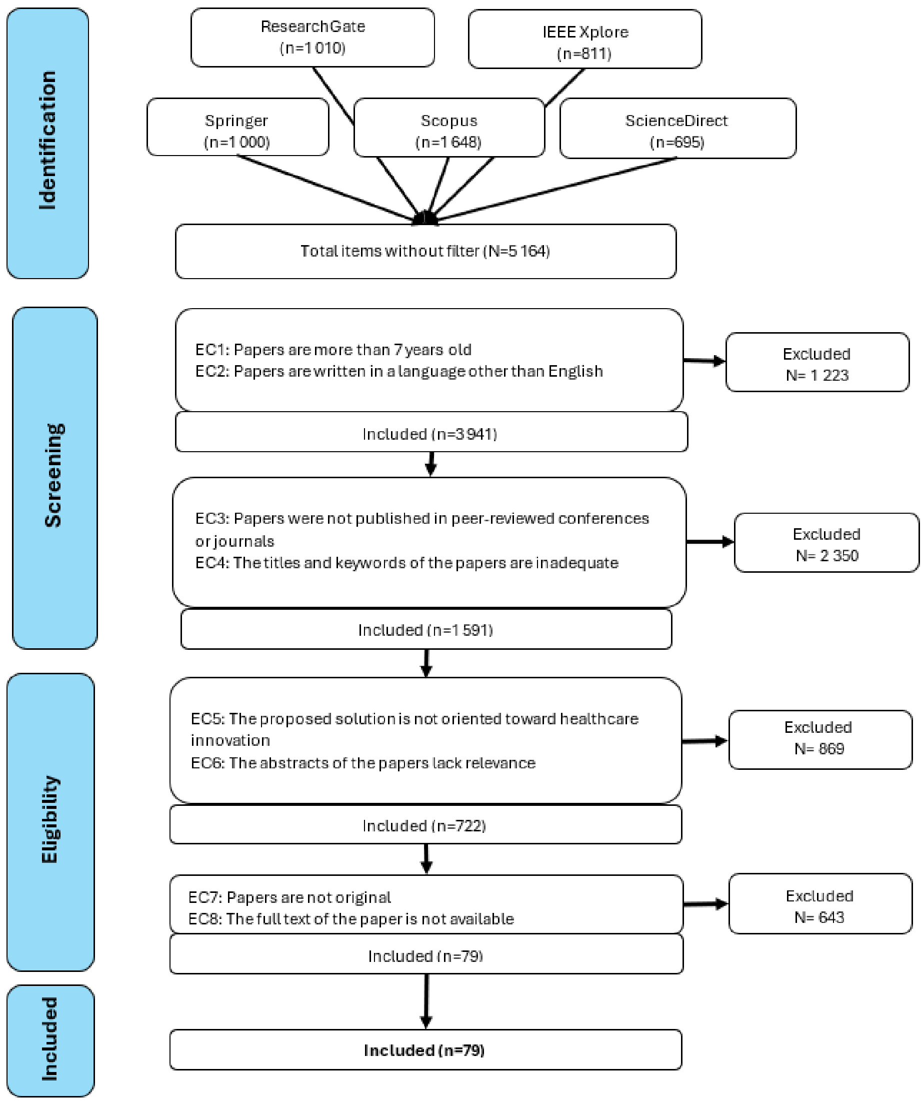

Figure 2. PRISMA flow diagram.

2.4. Synthesis of findings

The statistical analysis employed descriptive techniques using custom Python programs. A density map identified the global distribution of scientific publications by country, while a stacked bar and line chart depicted the temporal evolution from 2018 to 2024, highlighting annual trends and contributions from databases. Metrics such as absolute frequencies, relative frequencies, and temporal trends were used to analyze publication patterns. Python automated data processing and visualization generation, ensuring precision and replicability. This approach described general trends and specific patterns.

To address RQ1 and RQ2, advanced descriptive analyses were conducted. For RQ1, the efficiency criteria for 5G Technology (download speed, latency, coverage, and connectivity) were represented using pie charts to show their proportional distribution. For RQ2, Sankey diagrams were used to visualize the distribution of articles by quartile (Q1–Q4) and database (e.g., Scopus and Science Direct).

Regarding RQ4 and RQ5, Natural Language Processing (NLP) tools and mathematical models were applied. For RQ4, a bibliometric network based on keyword co-occurrence was generated. For RQ5, Callon's Equivalence Index and centrality and density calculations were used to build a strategic map that classifies topics into drivers, basics, specialized, and marginal categories. The entire analysis was implemented using Python, ensuring accuracy and robustness.

3. Results and discussion

This section presents and examines in depth the results obtained, contextualizing them in relation to existing literature and the objectives defined in the research. The implications of these findings are analyzed and contrasted with previous studies, aiming to provide a comprehensive and cohesive understanding of the topic in question.

3.1. General description of the studies

Figure 3 shows the number of papers by country, where it can be observed that the United States and China have the highest number of publications.

Figure 3. Number of papers by country.

The georeferenced chart emphasizes that the United States leads in publications on 5G technology in healthcare, followed by China, Germany, and the United Kingdom. Significant contributions from developing countries such as India and Brazil are also evident. This distribution reflects global interest, particularly in regions with advanced technological capabilities to implement 5G in healthcare systems.

Authors Gamboa-Cruzado et al. (2023) provide a figure showing specific percentages that quantify each country's contribution. In contrast, our figure visually emphasizes the predominance of these two countries in terms of the number of publications without specifying exact percentages.

The high concentration of research in advanced countries highlights the need to encourage studies in regions with fewer resources. Expanding research in underrepresented countries could enhance understanding of 5G implementation in diverse contexts, thereby promoting equitable adoption in the healthcare sector globally.

In **Figure 4**, papers by year and source are shown, illustrating the number of publications from 2018 to 2024 across various academic platforms.

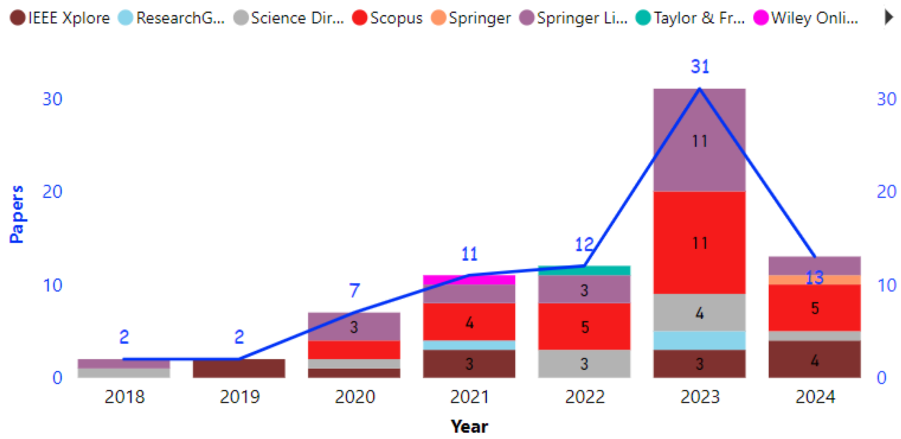

Figure 4. Papers by year and source.

The chart reveals a sustained increase in publications on 5G in healthcare since 2018, peaking in 2023. Scopus and Springer emerge as leading sources, followed by Taylor & Francis and Wiley in recent years. This trend reflects a growing interest in the implementation of 5G in healthcare, while the decline in 2024 might suggest a stabilization following the 2023 surge.

Villavicencio et al. (2024) present a figure that analyzes papers by year and source from 2020 to 2023, highlighting an increase in publications, with a higher concentration in Scopus, and selecting the most relevant papers of 2023 up to June as key references for the study. Their work focuses on a more recent and selective period, with an emphasis on the relevance of the papers for analysis. In contrast, Figure provides the number of publications from 2018 to 2024 across various academic platforms, offering a broader and longitudinal perspective on scientific output over several years and platforms.

The increase in the diversity of sources suggests wide acceptance and interdisciplinary collaboration in research on 5G in healthcare. Continuing access to these platforms and encouraging publication across multiple sources will benefit the dissemination of knowledge and innovation in the application of 5G in healthcare services.

3.2. Response to research questions

The answers to the research questions posed in this study are presented below, along with discussions and recommendations for future research.

RQ1: What criteria are applied to evaluate the effectiveness of 5G Technology?

Table 2 and **Figure 5** display the criteria used to measure the effectiveness of 5G Technology, accompanied by their respective references and the percentage of studies addressing them.

Table 2. Criteria for measuring effectiveness.

Criterion	**Reference**	**Quantity (%)**
Download speed	(Duan et al., 2021); (Lu et al., 2023)	2 (1.7)
Latency	(Ahad et al., 2019); (Ahmed et al., 2020); (Al-Quayed et al., 2023); (AlQahtani, 2023); (Ashleibta et al., 2021); (Baker et al., 2020); (Barakabitze et al., 2020); (Bhat et al., 2023); (Bilal et al., 2023); (Duan et al., 2021); (de Oliveira et al., 2023); (Jabbar et al., 2023); (Famá et al., 2022); (Frikha et al., 2024); (García et al., 2023); (Gupta et al., 2023); (Gupta and Gupta, 2024); (Hu et al., 2022); (Humayun et al., 2023); (Humayun et al., 2024); (Isravel et al., 2024); (Jaffer et al., 2023); (Kliks et al., 2018); (Kumar et al., 2024); (Kumar et al., 2023); (Le et al., 2021); (Minopoulos et al., 2023); (Moustris et al., 2023); (Priya and Malhotra, 2023); (Al Qathrady et al., 2024); (Rahman et al., 2024); (Arunglabi et al., 2022); (Tan and Chung, 2019); (Tan et al., 2023); (Tang et al., 2021); (Taniguchi et al., 2022); (Tian et al., 2023); (Verma et al., 2022); (Ya-Qin et al., 2022); (Zhang et al., 2020)	50 (43.5)
Coverage	(Ahad et al., 2019); (Ahmed et al., 2020); (Al-Quayed et al., 2023); (Ali et al., 2023); (Baker et al., 2020); (Barakabitze et al., 2020); (Duan et al., 2021); (de Oliveira et al., 2023); (Frikha et al., 2024); (Gupta et al., 2023); (Lu et al., 2023); (Priya and Malhotra, 2023); (Sabuj et al., 2022); (Tang et al., 2021); (Tzu-Wei and Chien-Lung, 2021)	25 (21.7)
Connectivity	(Ahad et al., 2019); (Ahmed et al., 2020); (Baker et al., 2020); (Barakabitze et al., 2020); (Bhat et al., 2023); (Cardoso et al., 2024); (Duan et al., 2021); (de Oliveira et al., 2023); (Famá et al., 2022); (García et al., 2023); (George et al., 2023); (Gupta et al., 2023); (Hameed et al., 2021); (Havey, 2020); (He et al., 2023); (Humayun et al., 2024); (Isravel et al., 2024); (Karad and Hendre, 2023); (Khan et al., 2022); (Khowaja et al., 2023); (Kliks et al., 2018); (Le et al., 2021); (Minopoulos et al., 2023); (Moustris et al., 2023); (Priya and Malhotra, 2023); (Al Qathrady et al., 2024); (Rahman et al., 2024); (Arunglabi et al., 2022); (Shukla et al., 2023); (Taniguchi et al., 2022); (Tian et al., 2023); (Vedaei et al., 2020); (Ya-Qin et al., 2022)	38 (33.0)

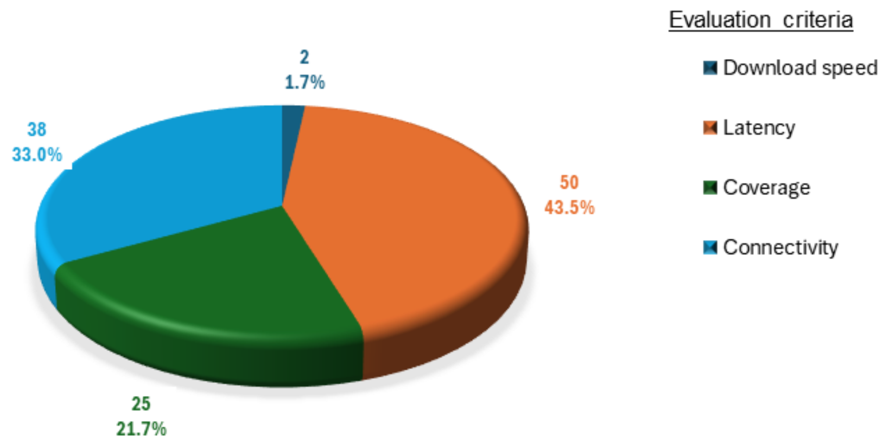

Figure 5. Number of papers by evaluation criterion.

The findings indicate that latency is the most prominent criterion, accounting for 43.5% of the references, underscoring its importance in the effectiveness of 5G. Connectivity follows with 33%, and coverage with 21.7%, highlighting the need for stable and extensive connections. Download speed, at 1.7%, appears to be a less prioritized criterion compared to the others.

In the study by Arque-Navarrete et al. (2022), the metrics presented in their table cover aspects such as job satisfaction, training, turnover, performance, retention, and teamwork, reflecting a more personnel-focused approach. On the other hand, Ferruzo et al. (2022) observe that decision-making emerges as the predominant criterion for evaluating the overall effectiveness of implementing Public-Private Partnerships (PPPs), as detailed in their table.

These findings emphasize that to optimize the deployment of 5G in high-demand applications, priority should be placed on reducing latency and enhancing connectivity and coverage. This suggests that future research and developments should focus on improving these factors to maximize the technology's effectiveness across various sectors.

RQ2: What quartile levels are the journals in that have published studies on the impact of 5G Technology on healthcare innovation?

Figure 6 illustrates the quartile levels of journals where research on the development of 5G Technology and its impact on healthcare innovation has been published.

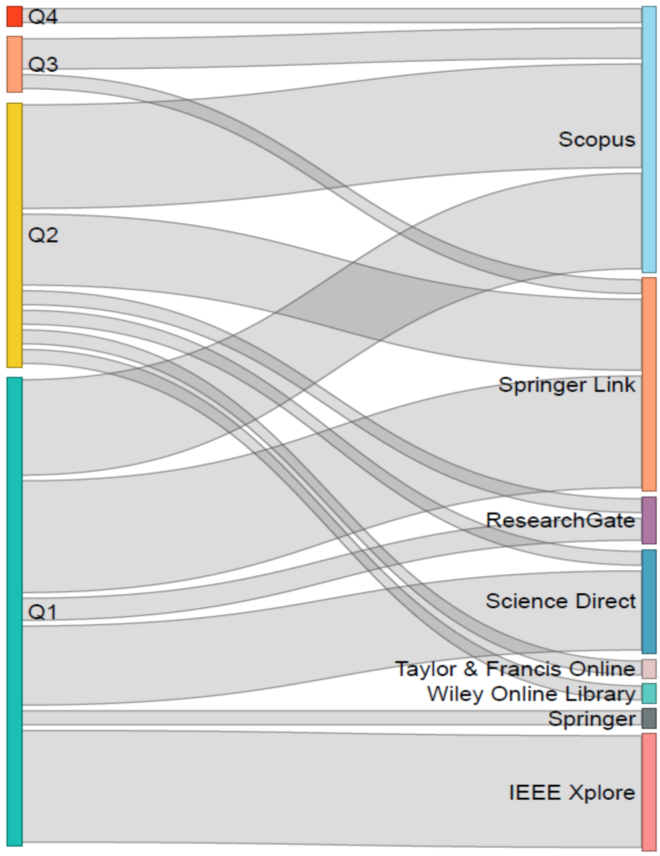

Figure 6. Papers by quartile and source.

The results show that most articles are published in Q1 journals, reflecting a high level of academic rigor in research on 5G in healthcare. Scopus and Science Direct lead in Q1 publications, while ResearchGate and Springer Link cover a wider diversity of quartiles. The low representation in Q3 and Q4 underscores the focus on high-impact research.

Authors Gamboa-Cruzado et al. (2024) highlight the distribution of quartiles across the various sources consulted in the review, with an emphasis on Q1, underscoring the connection between paper quality and origin. Similarly, Villavicencio et al. (2024) also use quartiles to classify publications based on their objectives, indicating the presence of papers that do not fit into any quartile and showcasing broader flows for databases with more studies.

These findings suggest that researchers interested in 5G technology and healthcare should focus on Q1 journals to achieve greater visibility and recognition. It also underscores the importance of academic sources like Scopus and Springer Link for accessing high-impact research in the field.

RQ3: What conceptualizations have been adopted to define 5G Technology?

Table 3 presents various conceptualizations of 5G technology, highlighting its role as the successor to the 4G network, as well as its capacity to enhance connectivity, enable remote monitoring, and drive applications in sectors like Fintech. Each perspective addresses a key aspect of 5G: from the technological vision and standards set by the ITU to its potential to support high-bandwidth and low-latency applications.

Table 3. Definition of 5G technology.

Perspective	Definition	Ref.
Technological Vision and Standards	5G is the next generation of the current 4G communication network, offering enhanced features such as high speed, capacity, and network scalability. The standards, capabilities, and technological vision for 5G are still under consideration and discussion. In 2015, the International Telecommunication Union (ITU) presented its roadmap for 5G in terms of 'IMT-2020.' The ITU has defined several parameters that can be considered key capabilities for 5G technology.	(Ahad et al., 2019); (Al-Quayed et al., 2023); (Cardoso et al., 2024)
Remote Monitoring and ML	5G communications would greatly facilitate the high-speed and highly reliable data collection through remote monitoring, inspiring new efficient methods in high-precision automatic diagnosis within the new ML paradigm. This work makes contributions in two primary areas.	(Ahmed et al., 2020); (AlQahtani, 2023); (Barakabitze et al., 2020)
Massive Connectivity in Fintech	5G technology promises high data speeds and low latency, enabling massive connectivity for IoT. Consequently, high data speeds should be leveraged for financial applications, such as mobile apps utilizing virtual reality for advertising, high-resolution (3D) investment charts, and monetary discount promotions through device-to-device (D2D) communications when users are near shopping centers, banks, etc. Overall, 5G technology will facilitate faster adoption of AI, IoT, deep learning, quantum computing, and blockchain in Fintech (Bhat and Alqahtani, January 2021). Furthermore, 5G will allow banks to scale their data processing and enhance user experiences.	(Ali et al., 2023); (Baker et al., 2020)
High Speeds and Low Latency	This technology provides extremely high speeds of up to 10 Gbit/s to support the growing use of mobile Internet, broadband above 6 GHz while increasing network density, and a low latency of just 1 ms.	(Bhat et al., 2023); (Bilal et al., 2023)

5G positions itself as a key platform for advanced technological applications due to its high data speeds and low latency. Beyond improving telecommunications infrastructure, it acts as a catalyst for innovation in sectors such as healthcare and Fintech, driving applications that require high precision and massive connectivity.

There was no specific paper for comparison in this definitions table; however, this table reflects the definitions of 5G Technology detailed in Table, grouped by different approaches, each offering a unique perspective on the capabilities and applications of this technology.

These definitions suggest that the development and adoption of 5G should be tailored to meet the specific needs of each sector, maximizing its benefits in critical applications. Additionally, the effective implementation of 5G could accelerate digital transformation in key areas such as healthcare and finance, underscoring the importance of a regulatory framework that supports its safe and efficient deployment.

RQ4: What are the most frequently used and prominent keywords based on the number of publications in research related to 5G Technology and its influence on healthcare innovation?

Figure 7 presents a bibliometric network of keywords related to 5G technology and its impact on healthcare. This visualization highlights the connections between key terms, revealing areas of interest and patterns of collaboration within the field.

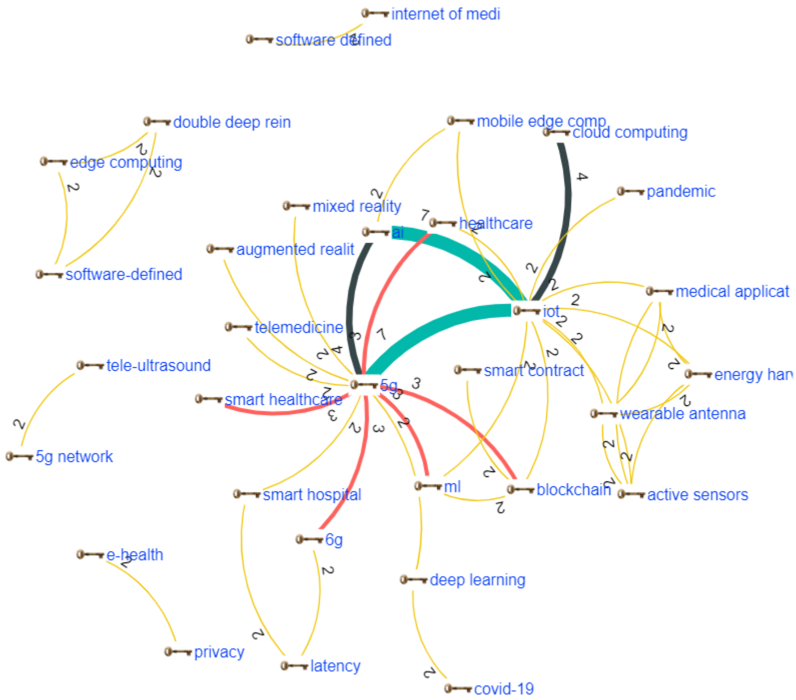

Figure 7. Bibliometric network by keywords.

5G technology emerges as a central axis for healthcare innovation, with terms like "IoT," "5G," and "AI" playing significant roles in transforming healthcare. Additionally, the use of "cloud computing" and "blockchain" underscores the importance of data security and management in this context. Terms associated with sensors and wearable devices indicate a trend toward remote monitoring and personalized treatments.

Authors Villavicencio et al. (2024) focus on general keyword connections, showing the strength of association through the thickness of the lines between nodes, enabling the identification of patterns and trends in the literature. Gamboa-Cruzado et al. (2023) also showcase keywords and their frequency of co-occurrence in studies on the impact of 5G in online gaming. Similarly, this Figure centers on the interconnection of specific key terms within the healthcare field, highlighting areas of interest and collaboration in research on 5G technology and its impact on healthcare.

The bibliometric network emphasizes research areas with high potential for strengthening digital health infrastructure, suggesting that future studies should focus on integrating emerging technologies with 5G. It also indicates the need for policies that support the adoption of these technologies, particularly in data security and equitable access.

Figure 8 shows the most impactful keywords in research on 5G technology and innovation in the healthcare sector.

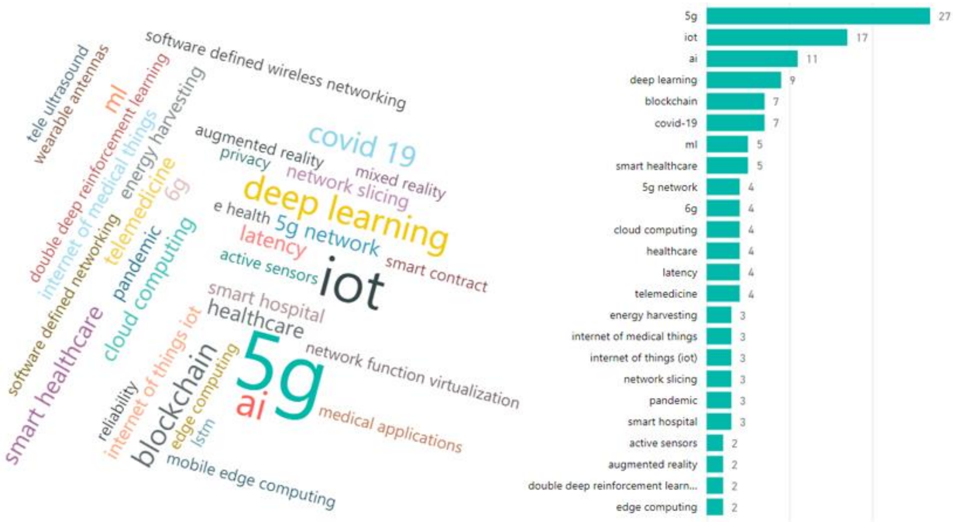

Figure 8. Most impactful keywords.

The findings show that keywords like “5G,” “IoT,” “AI,” and “deep learning” emerge as dominant terms, reflecting the studies’ focus on advanced connectivity technologies and data processing for healthcare. The high frequency of “blockchain” and “smart healthcare” indicates interest in security and intelligent care, while terms like “COVID-19” suggest an exploration of technology in pandemic contexts. The presence of concepts like “network slicing” and “latency” highlights the emphasis on network efficiency and responsiveness in 5G applications for critical healthcare.

Gamboa-Cruzado et al. (2023) concentrate on the impact of 5G technology in online gaming, highlighting terms such as “5G,” “online,” “video games,” “service,” “adaption,” and “gamification.” These terms reflect an interest in service adaptation and gamification within the gaming context. In contrast, Villavicencio et al. (2024) present a word cloud showcasing the most frequent keywords in general scientific production on 5G. Lastly, de Paula Ferreira et al. (2016) point out the most prevalent keywords among 789 papers, offering a broad perspective on predominant topics in the 5G literature.

The prominence of these keywords suggests that future research should focus on improving interoperability between these technologies and their application in the healthcare sector. Additionally, it underscores the need to explore integrated solutions that ensure both network efficiency and data security.

RQ5: What are the main thematic categories related to 5G Technology and its impact on healthcare innovation?

Figure 9 displays a Thematic Map of Centrality and Density, highlighting thematic categories associated with 5G Technology in healthcare. In this context, centrality indicates each theme’s relevance, while density represents its degree of development.

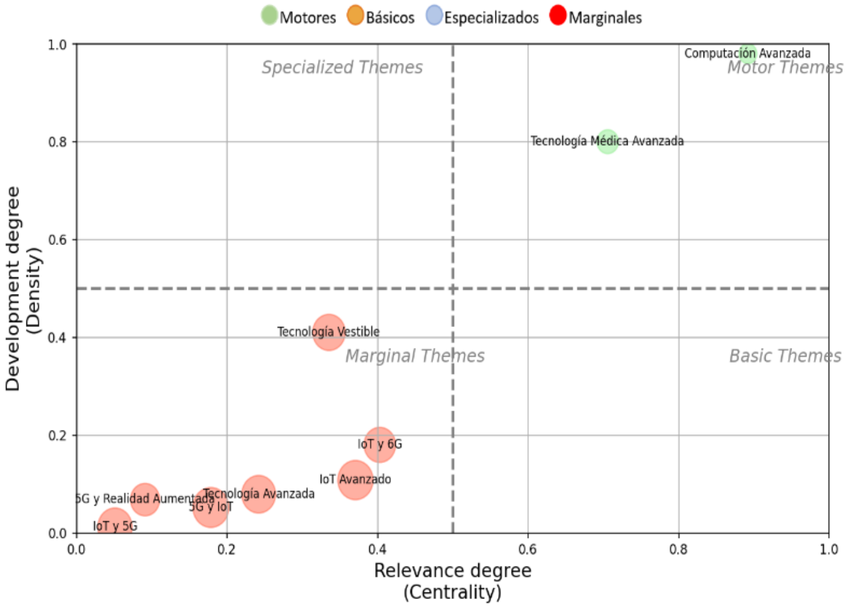

Figure 9. Centrality and density by themes.

Themes in the upper right quadrant, such as "Advanced Computing," have high centrality and density, suggesting they are fundamental and well-established drivers of 5G healthcare research. "Advanced Medical Technology" also appears in the motor themes quadrant, indicating its relevance and significant development level. In the lower left quadrant, "IoT and Augmented Reality" and "IoT and 5G" show low centrality and density, classifying them as marginal and less explored themes. "Wearable Technology" in the lower central quadrant has lower development and moderate centrality, indicating it is an emerging area with currently limited potential.

Authors Altarturi et al. (2023) present a similar upper right quadrant in their study, highlighting motor themes with high centrality and density, such as "Informatization," "agriculture," "e-commerce," and "COVID-19"—well-developed areas in agricultural e-commerce. In comparison, Figure of this paper shows "Advanced Computing" with high centrality and density values, while "IoT" and "5G" have null values in both metrics, indicating a less concentrated structure of connections in these specific themes.

Focusing on themes of high relevance but lower development, such as "Advanced Medical Technology," could maximize impact in the field. Additionally, emerging themes in the marginal quadrant, such as "5G and Augmented Reality," present opportunities for future innovations that expand the use of 5G in healthcare.

4. Conclusions

5G technology acts as a key catalyst for healthcare innovation, transforming connectivity and data processing in cutting-edge medical applications. This analysis highlights the importance of criteria such as latency and connectivity, reflecting the need for fast, stable connections to support demanding healthcare environments. The predominance of publications in high-impact journals (Q1) indicates significant interest and a rigorous standard in 5G healthcare research, suggesting a strong scientific foundation in this emerging field.

Regarding the conceptualization of 5G, a diversity of approaches demonstrates its versatility and potential, from remote monitoring to strengthening applications in sectors like Fintech, anticipating its transformative impact across multiple industries. The convergence with technologies such as IoT, artificial intelligence, and blockchain suggests an interdisciplinary outlook, where 5G not only expands current technological capabilities but also opens possibilities for developing more connected, secure, and efficient healthcare ecosystems.

Looking ahead, it is crucial to address the challenges of interoperability, cybersecurity, and scalability of 5G in clinical environments. Further research into specialized applications and the integration of this technology with other emerging innovations is necessary to improve healthcare efficiency and precision, as well as redefine quality and accessibility standards in medical services worldwide.

5. Limitations and future research

This study faces limitations due to variability in database results and keywords, which may have excluded relevant research. This is attributed to frequent database updates and algorithm adjustments. Additionally, the rapid evolution of 5G makes it challenging to fully capture recent advancements.

For future research, it is recommended to broaden the bibliographic search by incorporating a wider range of databases, implement advanced text mining and natural language processing techniques to identify more comprehensive and relevant key terms, and develop a standardized and replicable framework to comprehensively evaluate the effectiveness of 5G in the healthcare domain.

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