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Review

5G Technology in the Digital Transformation of Healthcare, a Systematic Review

Michael Cabanillas-Carbonell [1,*], Jorge Pérez-Martínez [1] and Jaime A. Yáñez [2]

1 Escuela Técnica Superior de Ingenieros de Telecomunicación, Universidad Politécnica de Madrid, 28040 Madrid, Spain
2 Vicerrectorado de Investigación, Universidad Privada Norbert Wiener, Lima 15046, Peru
* Correspondence: mcabanillas@ieee.org

Abstract: The world is currently facing one of the biggest problems related to health and the quality of healthcare. According to the goals outlined by WHO in the blueprint for sustainable development (SDG3), one of its objectives is to achieve universal health coverage and ensure a healthy lifestyle. In this regard, it is important to monitor and track the impact of applications that help address this problem. This systematic review provides an analysis of the impact of the 5G network on the use of apps to improve healthcare. An analysis of 343 articles was performed, obtaining 66 relevant articles, the articles were categorized into research conducted with fiber optic backbone network as well as future research. The main medical applications were identified as: telesurgery, mobile ultrasound, biosensor technology, robotic surgery and connected ambulance. In addition, it is classified and answer questions such as the most used to improve medical care and health quality, 5G-based applications used in media to improve medical care and health quality, databases and programming languages in telemedicine are the most used in 5G-based applications, the functionality available for telemedicine based on the use of 5G-based applications.

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

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1. Introduction

Health is a great problem that has plagued us since ancient times. The World Health Organization (WHO) aims to improve the health and well-being of populations throughout life [1]. Since its inception, the United Nations has worked to promote and protect health worldwide [2]. In 1948, the WHO assumed responsibility for the Universal Categorization of Pathologies, which became the worldwide standard for conceptualizing and recording pathologies and other health problems [2]. In September 2015, the Sustainable Development Goals were established [3] The Sustainable Development Goal 3 (SDG 3) is called "Good Health and Well-being" [4], and it aims to ensure a healthy lifestyle and promote wellness at any age as a fundamental goal to sustainable development [5]. Each SDG has various targets that further detail the goal; for instance, SDG target 3.8 aims to achieve universal health coverage [6].

Recent World Bank and WHO studies show that even before the pandemic, more than 500 million people were pushed deeper into poverty because they had to pay for health care out of their own income [7]. The COVID-19 pandemic likely aggravated the situation and hinder two decades of global progress toward universal health coverage. Recent estimates indicate that in 2020 governments worldwide spent approximately 2% of their healthcare budgets on mental health, and many low-income countries reported less than 1 mental health worker per 100,000 people [7]. Healthcare systems in many nations are also facing challenges generated by the pandemic, population aging, and an increasing burden of lifestyle-related pathologies.

Nevertheless, significant progress has been made in optimizing the health of millions of people. Maternal and infant mortality has decreased, life expectancy continues to increase worldwide, and the fight against some infectious diseases is steadily advancing [8]. WHO's Global Health 2020 World Health Statistics on global health showed that access to essential health services improved overall between 2000 to 2017, with the largest increases in lower-middle-income and low-income countries [2]. The WHO and UNICEF jointly carried out the consultation on the global report [9] to discuss and review the population's access to assisted technology, including training and best practices to minimize gaps by creating an appropriate data usage environment. These technologies are based on 3G, 4G, and currently at their peak, fifth-generation (5G) technologies and their implication as a benefit or sacrifice [10].

The pioneer of 5G technology was South Korea offering a mobile hotspot for the first time in December 2018 [11]. Although the 5G network is still under development, some countries, including China, the United Kingdom and the United States of America, and a few other developed countries expect to deploy commercial 5G networks by 2025 [12]. Unlike existing wireless networks, 5G offers a high throughput and data rates, lower latency, a high volume of energy-efficient device-to-device connectivity, high reliability, and mobility support [13]. Likewise, the 5G network will significantly increase the capacity to handle massive simultaneous connections between virtually all smart devices of the future [14]. As the number of digital devices with 5G connectivity increases dramatically, the level of disruption in radio frequency (RF) space exposure is still under scrutiny. The operation of 5G will result in a strong and unprecedented electromagnetic field exposure for any living object or organism that stays or moves in an urban environment. It is important to point out that the 5G network is an RF-based technology that uses the electromagnetic spectrum (just like the 4G spectrum) to transmit information involving radiation (the emission of energy) [15]. Radiation is characterized by power levels in electromagnetic fields (EMFs) and is separated into two groups: ionizing (or higher frequency radiation) and non-ionizing (or lower frequency radiation) [16,17].

The need to add more 5G base stations has caused widespread public concerns about its likely negative health effects [18]. It has been reported [19] the potential link between radiation from cell phones using 5G technology and its effect on brain cancer, generating a gigantic dispute over the risks involved [19]. The deployment of the 5G network is a major concern in many countries, which has led many citizens to try to implement a moratorium until intense research is conducted on the adverse effects on human health and the environment. In September 2017, a call for a moratorium was sent to the European Union (EU) and signed by more than 390 international scientists and physicians [20], the appeal is still open [21] for approval by scientists or physicians.

5G digital technology can contribute to more effective medical research, diagnosis, and treatment, as well as improve healthcare services for healthcare professionals and patients anywhere and anytime [22]. In 2019 consumers downloaded 204 billion apps, this being 45% more than in 2016, with USD 120 billion spent on apps [23]. By 2021, 67% of people worldwide subscribed to mobile devices, of which 75% used smartphones [24]. Mobile health solutions are increasingly important in achieving SDG 3: Good health and well-being. In most countries, the percentage of people using cell phones for health purposes has increased [25], with seven years to go until the SDG deadline, stakeholders are renewing efforts to achieve the SDGs, and mobile technologies play a pivotal role.

5G technology will provide much faster data speeds and support various novel applications through artificial intelligence (AI) such as virtual and augmented reality [26,27]. Studies have also been carried out involving the use of technology for the auxiliary diagnosis of breast cancer using deep learning technology [28]. On the other hand, in other fields such as telerobotic surgery, large-scale advances have been made in the last few years regarding its contribution [29], as well as surgical procedures performed remotely with the support of the 5G network [30].

The objective of the research was, therefore, to analyze different articles where the scopes related to the deployment of 5G technology in healthcare can be highlighted in order to obtain different alternatives and perspectives to carry out new interventions to achieve an improvement in health and healthy life.

2. Methodology

2.1. Type of Study

A systematic literature review was used to generate this article [31], as a means of categorizing and searching for information.

2.2. Research Questions

The suggested research questions (RQs) for the present research are:

RQ1. Which countries have the most research, in the last 5 years, related to technological advances in healthcare using 5G networks?

RQ2. Which digital technologies are the most used to improve medical care and health quality?

RQ3. What are the 5G-based applications used in the media to improve medical care and health quality?

RQ4. Which database and programming languages in telemedicine are most commonly used in 5G-based applications?

RQ5. What is the functionality available for telemedicine based on the use of 5G-based applications?

2.3. Search Strategies

To answer the questions, a collection of articles was made from the main databases Scopus, IEEE Xplore, ScienceDirect, IOP Publishing, and EBSCO Host. This allowed the collection of 343 scientific articles (Figure 1). When applying the search for all the information related to the research topic, the following keywords were considered: "impact AND "5G technology AND health", "5G AND network", and "Health implementing software 5G".

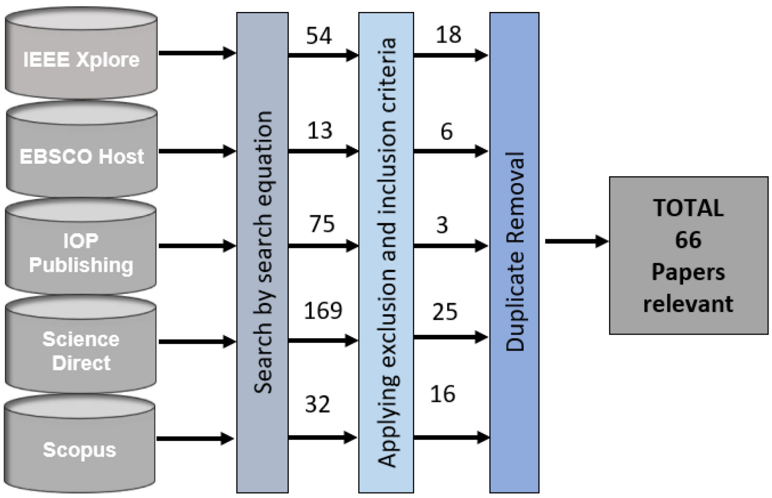

Figure 1. Item inclusion chart.

2.4. Inclusion and Exclusion Criteria

The following inclusion and exclusion criteria were applied for the systematic review study (Table 1).

Table 1. Inclusion and exclusion criteria.

		Criteria
Inclusion	I01	Articles related to 5G-based digital technologies used for medical care.
	I02	Articles that apply a methodology, a model, and/or a method in their development.
	I03	Articles related to the impact of 5G networks on healthcare.
	I04	Articles published since 2018.
Exclusion	E01	Unrelated articles on 5G-based digital technologies used for health care.
	E02	Articles that do not apply a methodology, model, and/or method in their development.
	E03	Articles that do not partially answer the research questions.
	E04	Articles published prior to 2018.

3. Results

A total of 343 articles were found in the databases related to the research topic, from which articles that were duplicates, did not meet the inclusion criteria, or did not contribute to the research were discarded. After reviewing the articles, 66 articles were selected and chosen for the systematic review. Figure 2 shows the automation carried out based on the PRISMA method [32], and shows the importance of this method in a detailed and transparent explanation of the article review.

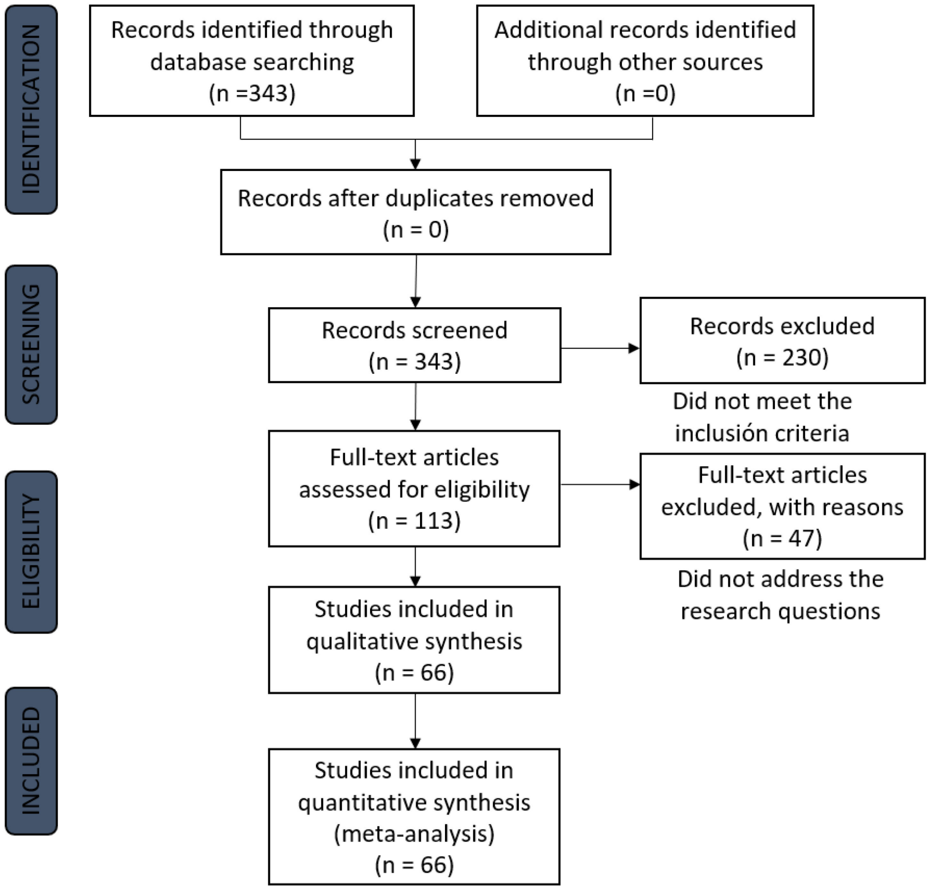

Figure 2. PRISMA diagram methodology.

Figure 3 shows the number of items found by the database.

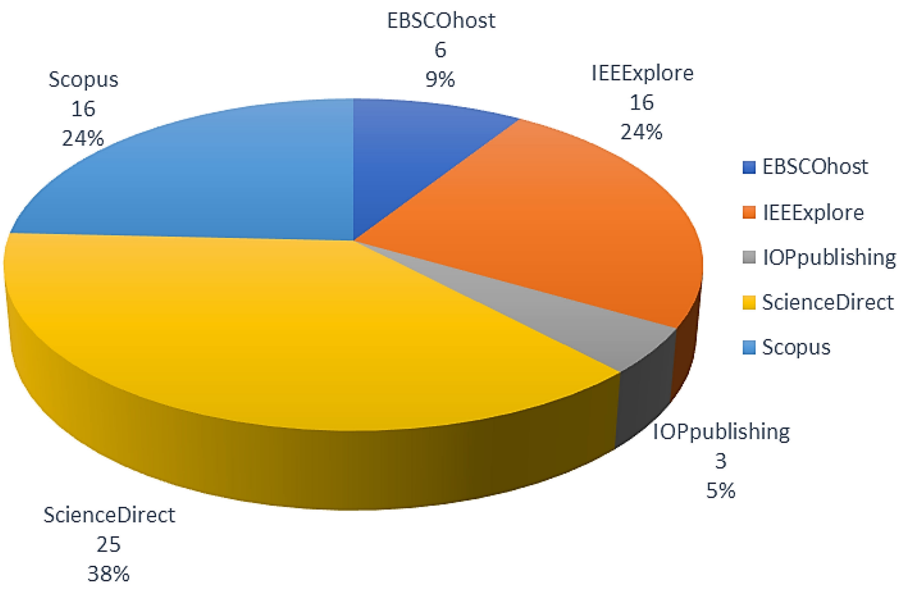

Figure 3. Articles by database.

Figure 4 shows the number of articles published per year and per database.

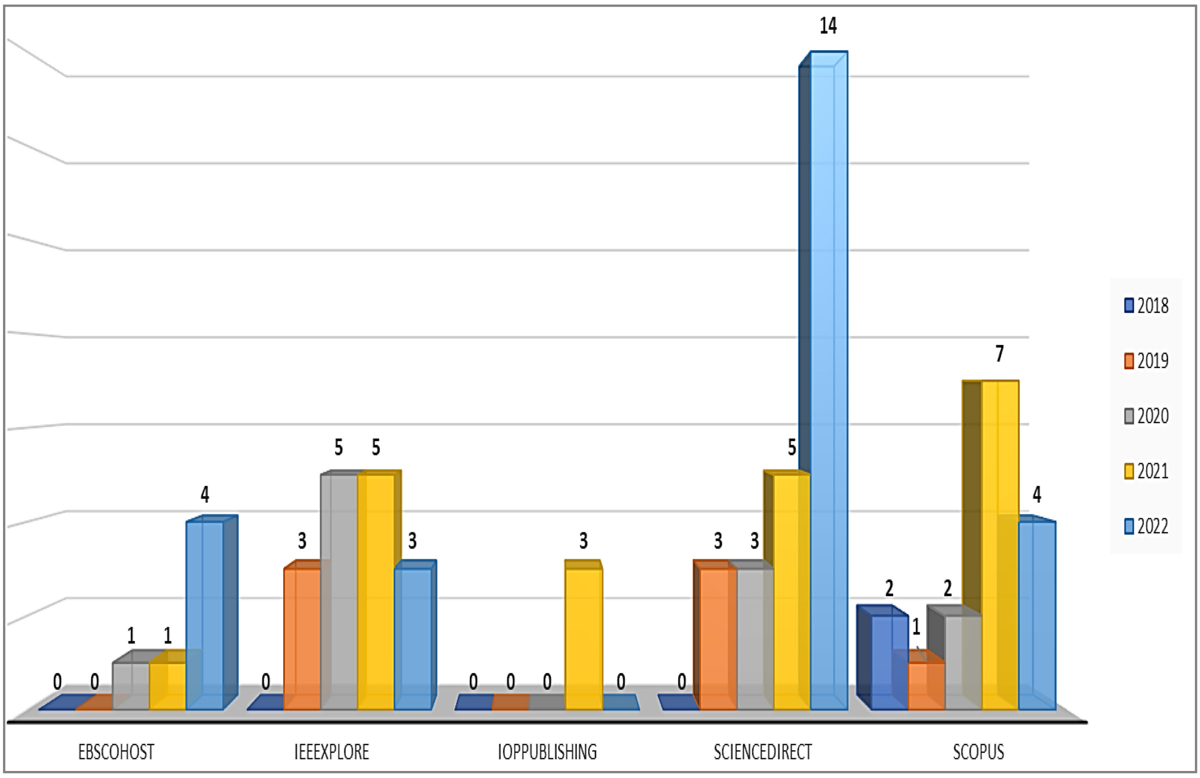

Figure 4. Articles by year and database.

Alfred Lotka introduced the term "bibliometrics" in 1926 by analyzing the production patterns of different authors, concluding with the presentation of the first criteria for bibliometrics [33]. Bibliometrics is part of scientific research, and it is a very effective technique to retrieve, evaluate and analyze, in a statistical way, quantifiable data in the academic literature, merits of a given subject area, or a particular publication containing indicators to obtain a better evolution of the research direction. It is hoped that bibliometric analysis will help fill research gaps, open new perspectives for future research, and foster collaboration [34]. The VOSviewer software tool allows us to build and visualize bibliometric networks (including individual publications, authors, scientific journals) and it is based on co-authorship relationships, co-citation, bibliographic linkage, citation networks, and co-occurrence of important terms drawn from a body of scientific literature [35]. To perform this bibliometric analysis, we used the VOSviewer software, which helped us with the keyword concurrence analysis and the full recognition method. From this, visualization maps were created, which can be seen in Figure 5.

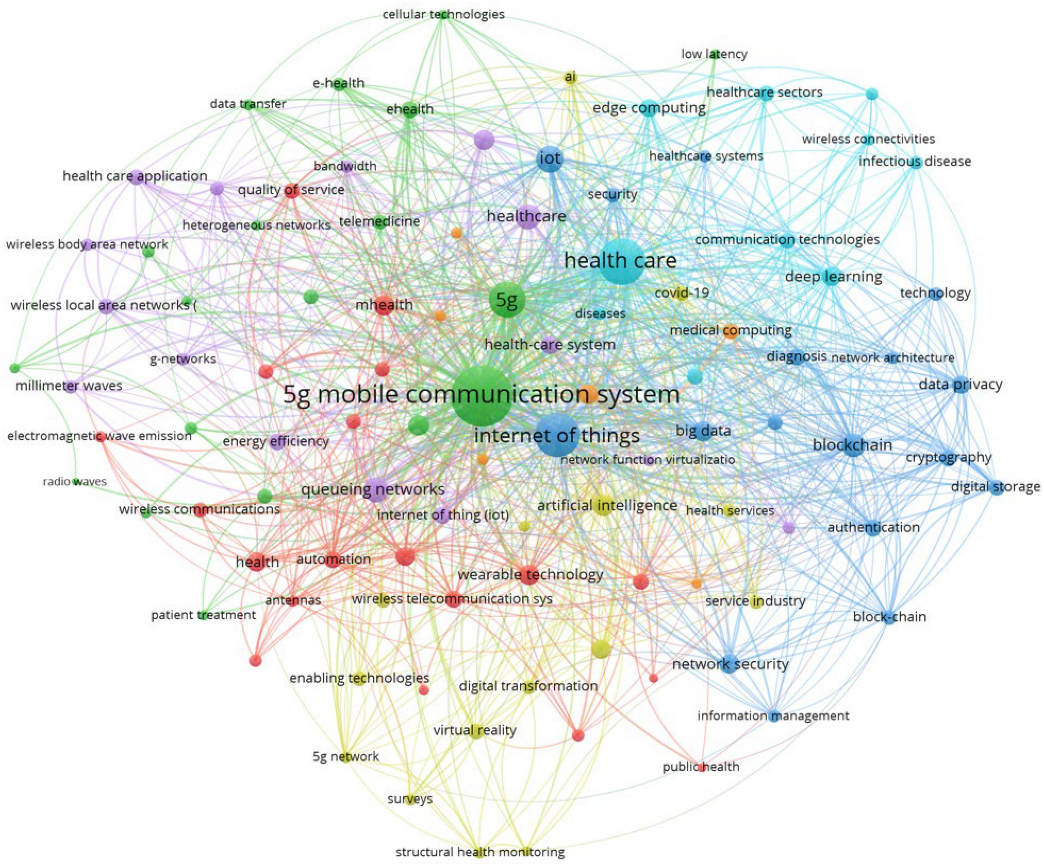

Figure 5. Network visualization of documents available in the Scopus database based on bibliometric analysis.

Cluster 1 (Red): Related to the impact and use of technology and health, which is the main part of our search, containing: mhealth, health monitoring, and healthcare services.

Cluster 2 (Green): Related to mobile technologies where it groups 19 items, including: 5G mobile communication system, mobile technology, and wireless technologies.

Cluster 3 (Blue): Related to the type of data and its processing, including: blockchain, big data, deep learning, and edge computing.

Figure 6 shows the word cloud obtained from the keywords of the systematized articles, using R Studio software for this bibliometric analysis. The following words stand out: 5G, internet of things, and healthcare.

Figure 7 shows the tree map with the percentages of the most recurrent words based on the bibliometric analysis.

Figure 8 shows the classification of the 66 selected articles by country analyzed according to the digital tools used.

Figure 9 shows the ranking of the 66 selected articles by continent analyzed according to 5G technologies and their application in healthcare.

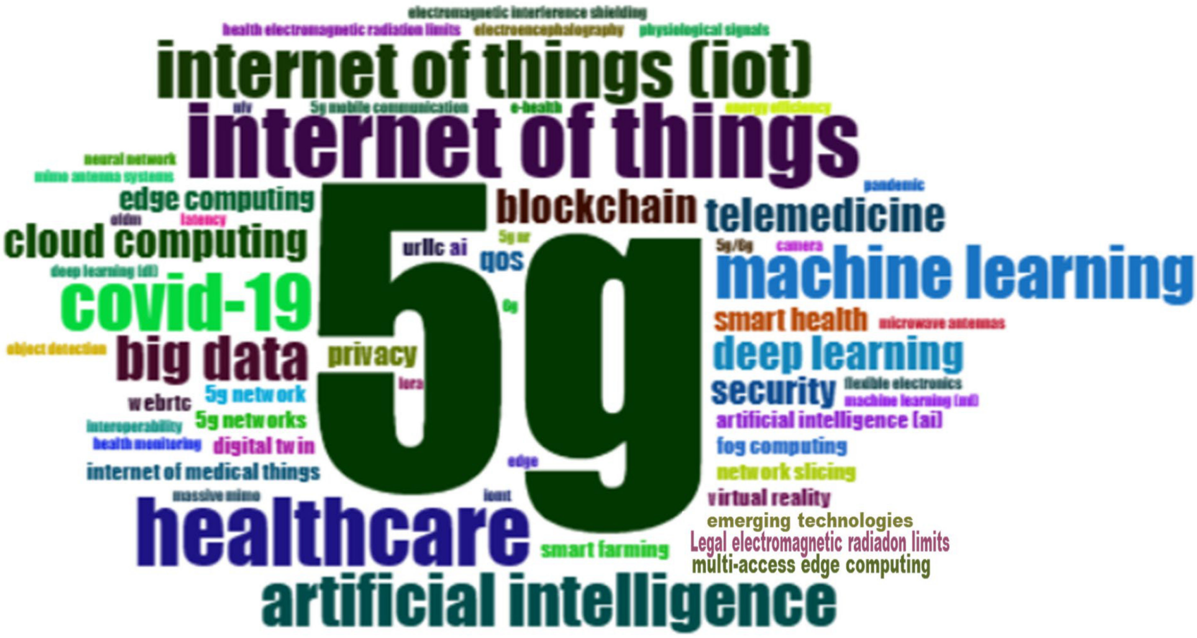

Figure 6. Overlay visualization of documents available in the Scopus database: word cloud.

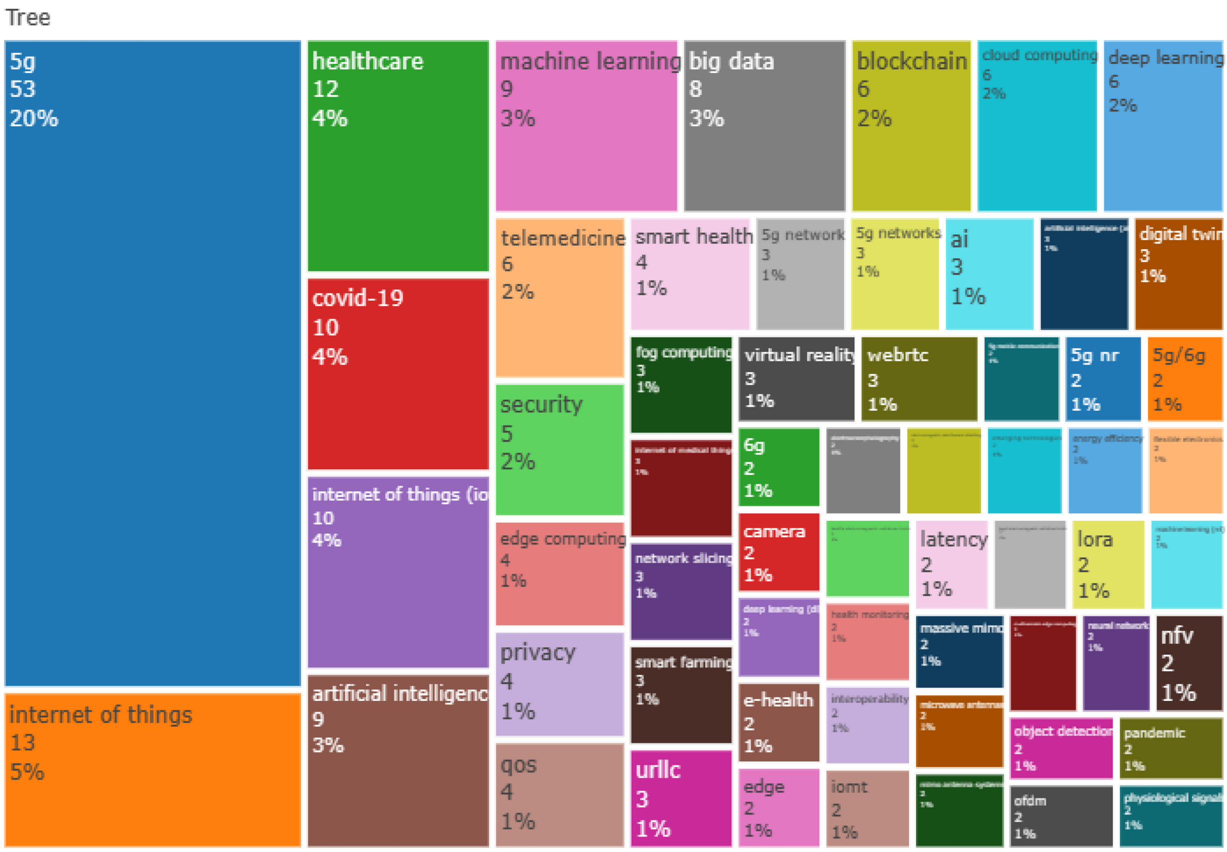

Figure 7. Visualization of the documents based on bibliometric analysis.

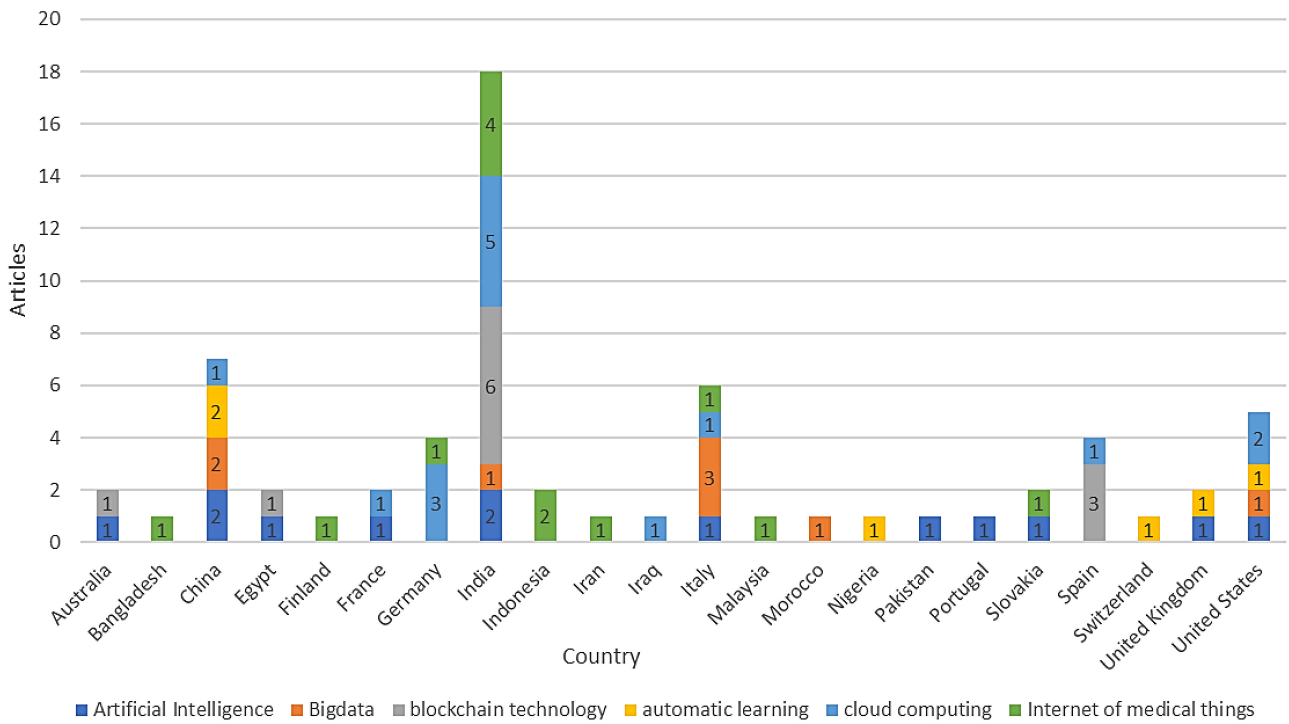

Figure 8. Distribution of articles by digital tools and country.

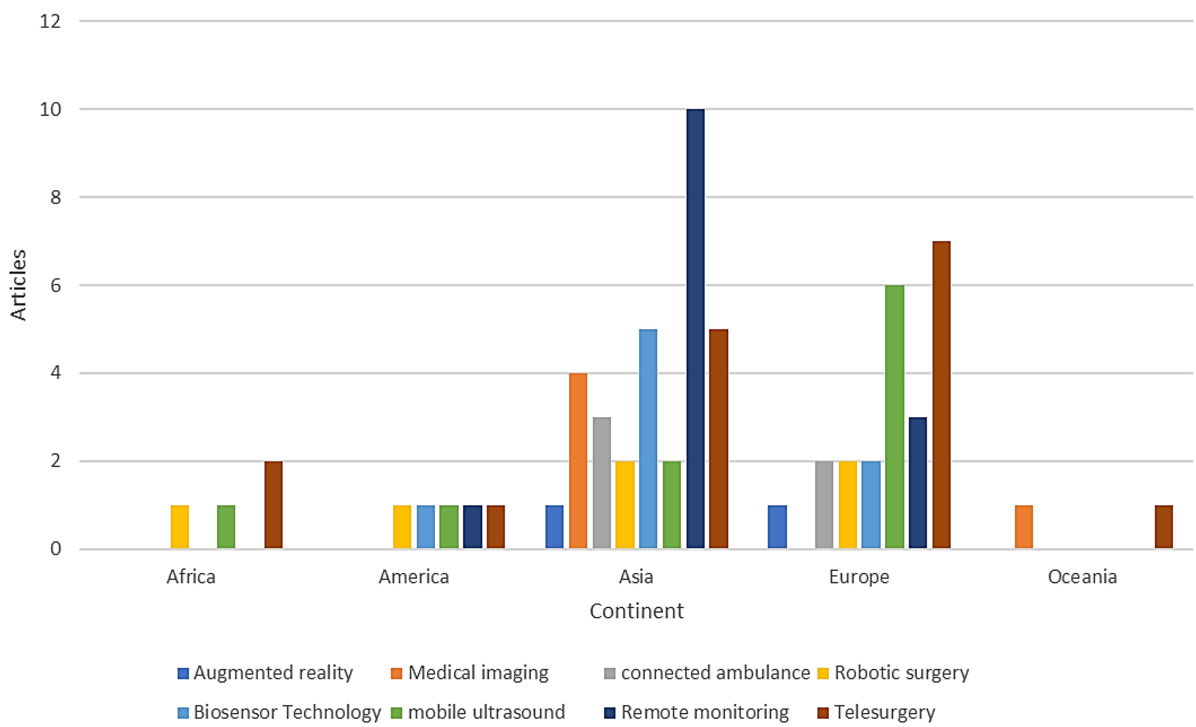

Figure 9. Distribution of articles by application and continent.

4. Discussion

This systematic literature review aims to provide answers to the proposed questions.

4.1. RQ1. Which Countries Have the Most Research, in the last 5 Years, Related to Technological Advances in Healthcare Using 5G Networks?

Within the analyzed articles, there are studies as future projects or pilot projects, as opposed to studies implemented through the 5G backbone; Figure 10 shows the number of articles according to their implementation by continent. Research conducted in Europe, followed by Asia, presents the highest percentage of implementation.

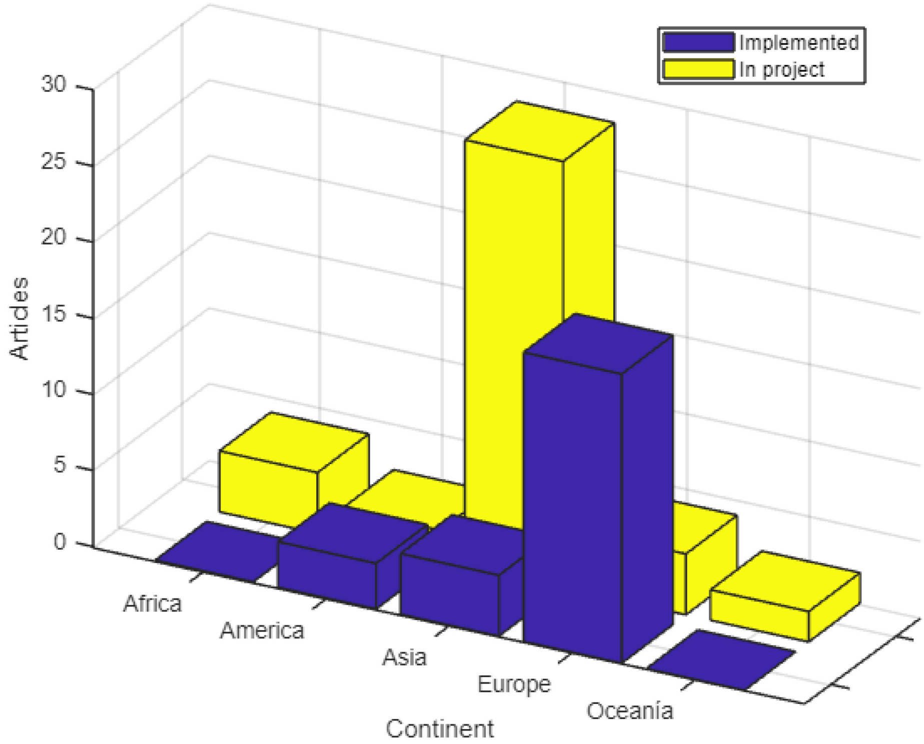

Figure 10. Distribution of articles by continent according to its implementation.

The United Nations gives us the figures for the world population [36]. According to this, we can obtain the density of research launched (implemented) through the 5G backbone network, as shown in Table 2 there is a higher density in the European continent followed by the Asian continent.

Table 2. Density by implemented projects.

Continente	Population Million	Implemented	In Project	Total	Density (Implemented/Population) × 1000
Asia	4600	4	28	32	0.87
Oceania	43	0	2	2	0.00
America	1000	3	2	5	3.00
Africa	1300	0	4	4	0.00
Europe	750	19	4	23	25.33
Total		26	40	66	

Figure 11 shows the number of articles published by country in total; India has the largest number with a total of 18 selected articles, China has 7 publications, Italy 6, the United States 5, Germany 5 and Sapin 4, with a smaller number in Australia, Germany, Egypt, Indonesia, Slovakia, United Kingdom, Switzerland, Portugal, Pakistan, Nigeria, Morocco, Malaysia, Iraq, Iran, Finland, and Bangladesh.

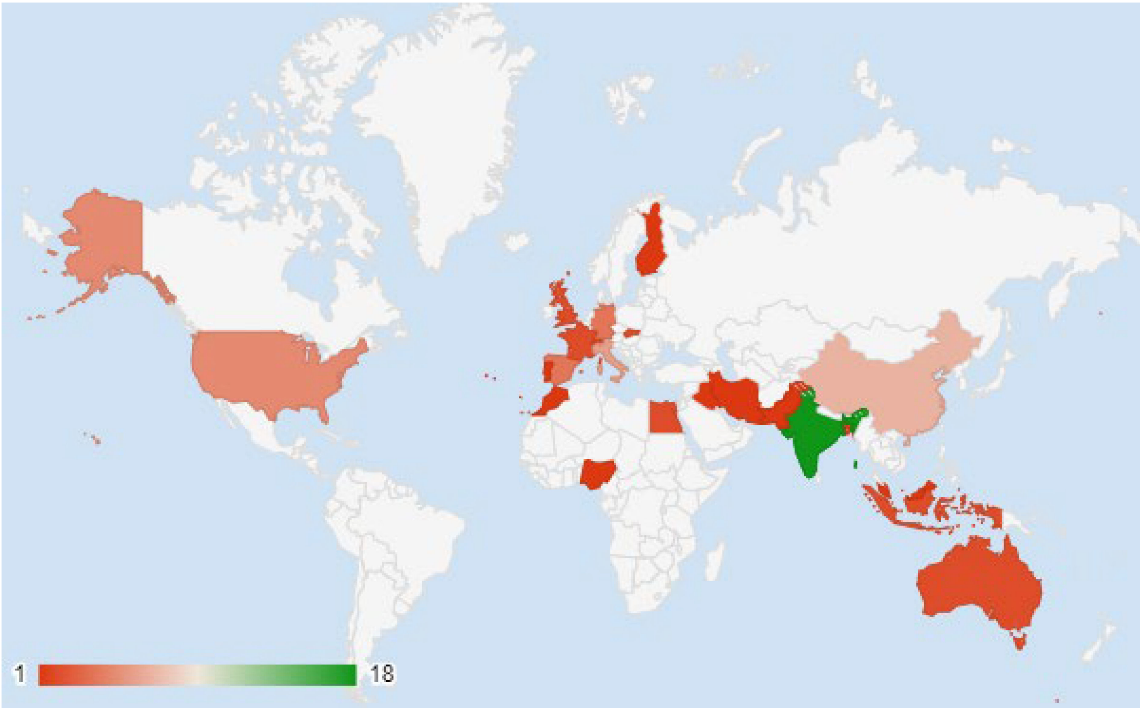

Figure 11. Distribution of published articles in total by country.

Figure 12 shows in detail the articles published by country in the project phase regarding 5G backbone network implementations, highlighting countries such as Germany, United States, Italy, China, and Spain, among others.

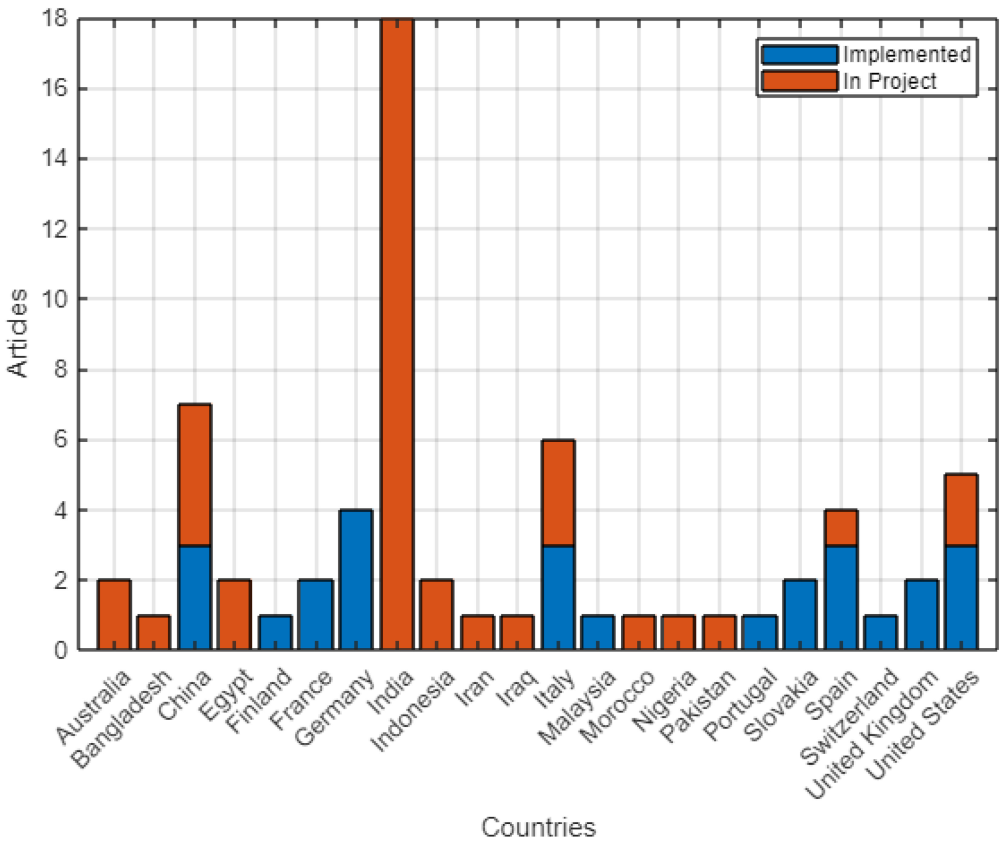

Figure 12. Distribution of published articles by country.

4.2. RQ2.Which Digital Technologies Are the Most Used to Improve Medical Care and Health Quality?

Figure 13 shows the most relevant topics analyzed with Digital Tools: cloud computing (15), artificial intelligence (13), the internet of medical things (13), blockchain technology (11), big data (8), and automatic learning (6).

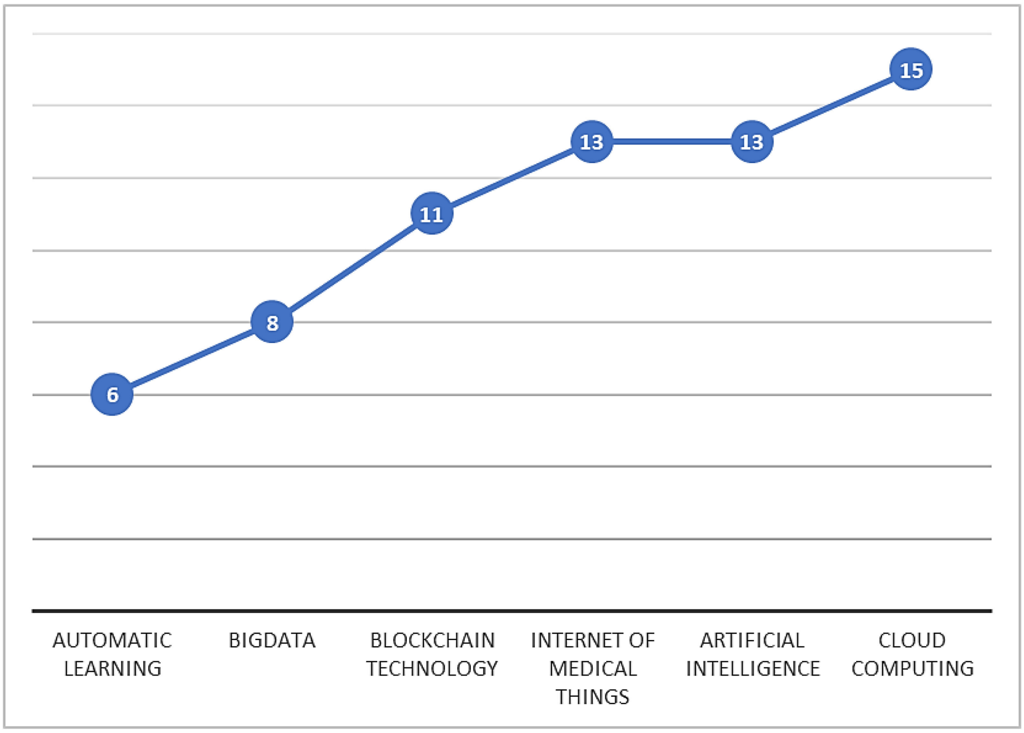

Figure 13. Distribution of research topics according to Digital Tools.

According to Table 3, it can be seen that the most widely used technology is based on cloud computing, which can enable better medical care and health quality.

Table 3. Articles classification according to digital tools research.

Categories	Quantity	Articles
Cloud computing	15	[37,38,38–50]
Artificial intelligence	13	[51–63]
Internet of medical things	13	[46,59,64,64,65,65–72]
Blockchain technology	11	[73,73–82]
Big data	8	[83–90]
Automatic learning	6	[91–96]

4.3. RQ3. What Are the 5G-Based Applications Used in Medicine to Improve Medical Care and Healthcare Quality?

Figure 14 shows the articles according to their application in medicine using 5G technology highlighting: telesurgery, remote monitoring, mobile ultrasound, biosensor technology, robotic surgery, and connected ambulance.

Table 4 shows the articles that evidence the use of 5G technology in healthcare, highlighting that the most used application was telesurgery.

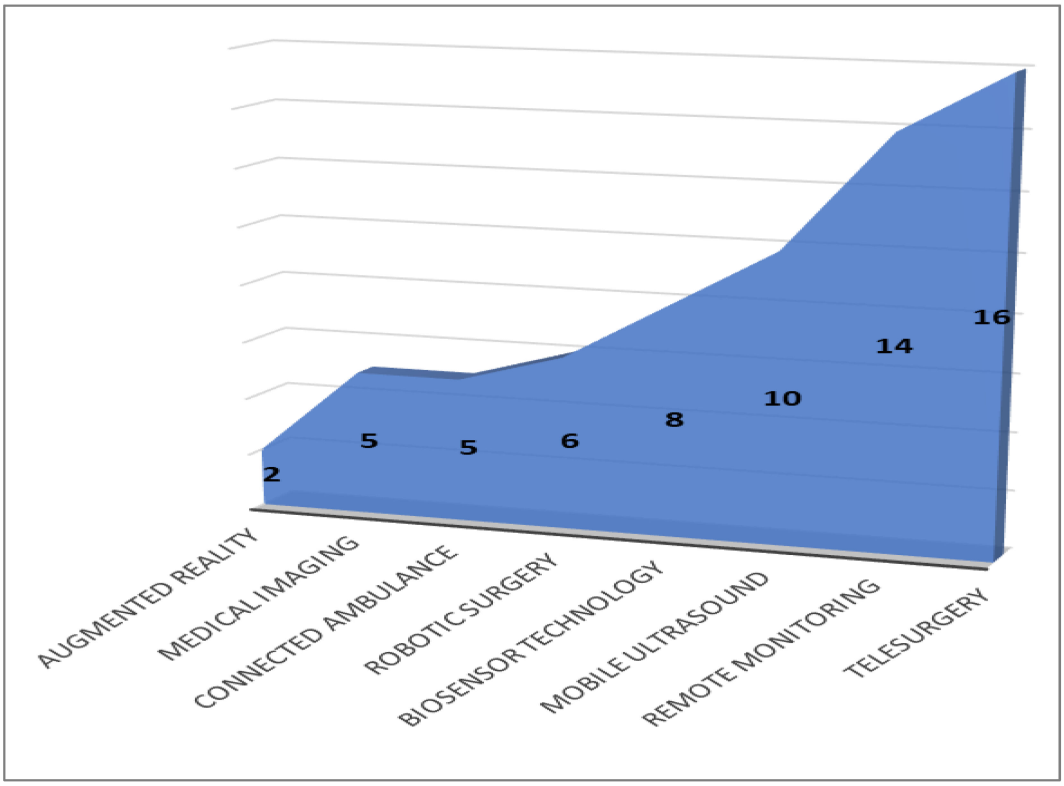

Figure 14. Distribution of research articles by its application in medicine.

Table 4. 5G-Based Applications Used in Medicine.

Categories	Quantity	Articles
Telesurgery	16	[47,55–58,60,61,69,73,73,74,76,77,81,82,92]
Remote monitoring	14	[37,44,45,50,63–65,68,78,84,87,88,90,95]
Mobile ultrasound	10	[38,38,42,49,59,72,83,86,89,93]
Biosensor Technology	8	[39,40,46,67,70,85,94,96]
Robotic surgery	6	[43,52,54,59,62,75]
Connected ambulance	5	[46,48,64,65,79]
Medical imaging	5	[41,51,66,71,80]
Augmented reality	2	[53,91]

Table 5 allows us to highlight the articles according to their application in medicine using 5G technology.

4.4. RQ4. Which Database and Programming Languages in Telemedicine Are Most Commonly Used in 5G-Based Applications?

Figure 15 shows that the database mostly used in medicine applications is Oracle. Figure 16 also shows that the programming language mostly used in telemedicine applications is Java.

Table 5. Detail of articles for application in medicine using 5G.

Categorie	Article	Descriptión
Telesurgery	[47]	Proposed system for remote patient monitoring (RPM) based on 5G network, allowing to provide a wide range of medical services.
Mobile ultrasound	[72]	Clinical evaluation of telemedical transmission and applicability of ultrasound probes between ambulance and remote hospital sites implementing core slicing over 5G network.
Connected ambulance	[46]	Use of 5G technology, mobile edge computing, and heterogeneous network management for healthcare network service flows applied to the connected ambulance.
Robotic surgery	[54]	A multisensor fusion method based on interpretable neural networks (MFIN) for BSN in medical scenarios of doctor-robot-human interaction.
Remote monitoring	[47]	Proposal for a 5G remote patient monitoring (RPM) system to deliver a wide range of healthcare services and identify the potential impact of 5G in Spain on the delivery of eHealth services.
Biosensor Technology	[97]	Wearable biosensors for wearable devices and their use in healthcare monitoring.

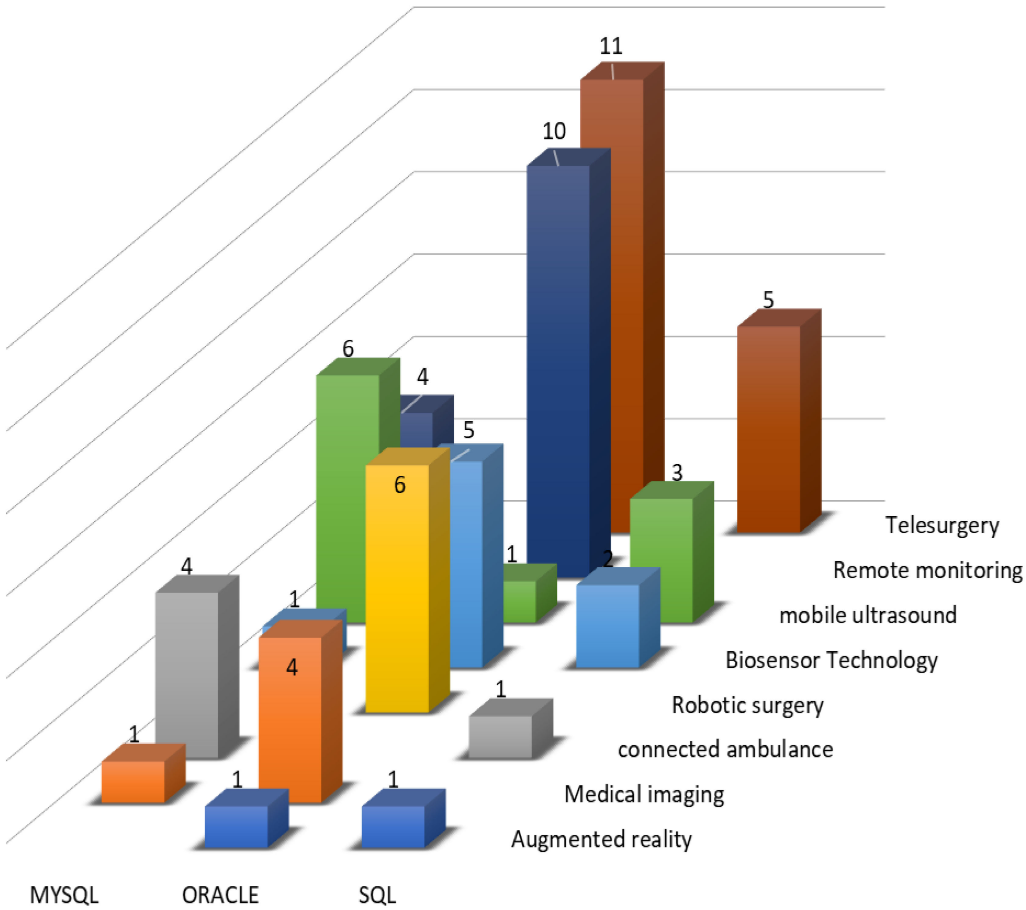

Figure 15. Distribution of medicine applications by database.

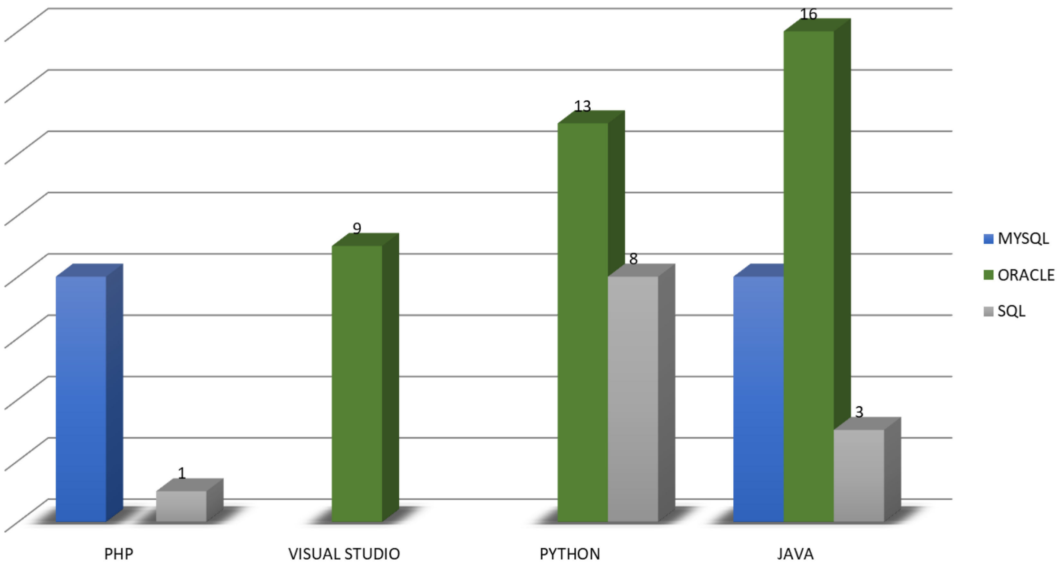

Figure 16. Distribution of programming languages used in telemedicine.

4.5. RQ5. What Is the Functionality Available for Telemedicine Based on the Use of 5G-Based Applications?

According to Figure 17, it can be seen that there is greater scope according to its functionality in telemonitoring allowing the use of 5G-based technologies to obtain routine or special information regarding the patient's condition such as: physiological variables, test results, images, and sounds. This can allow deciding when and how to adjust the patient's treatment.

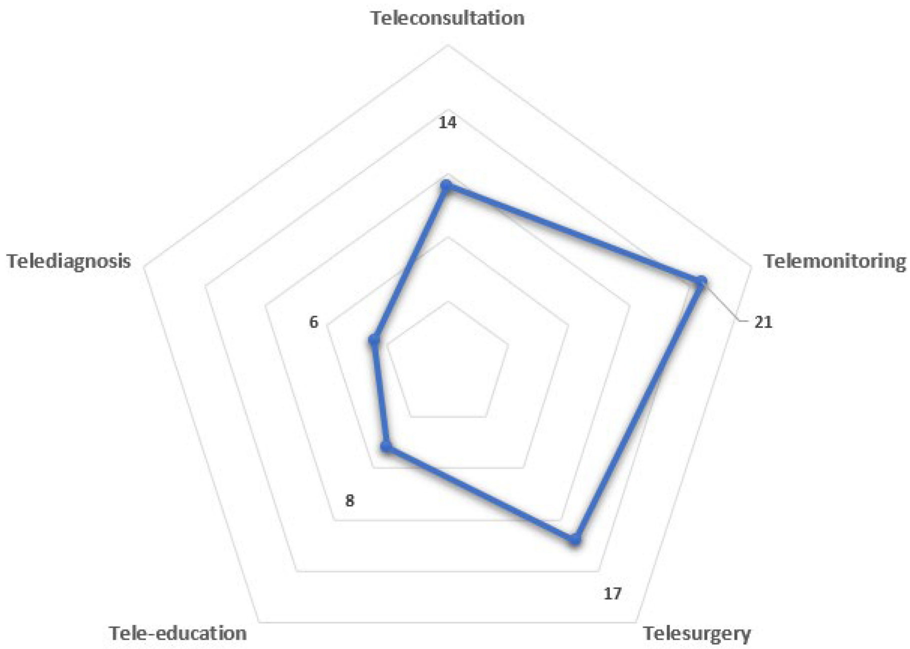

Figure 17. Distribution of telemedicine use of 5G-based applications.

Table 6 highlights the items according to the functionality in telemedicine using 5G technology.

Table 6. Classification of items according to their functionality in telemedicine.

Categories	Quantity	Articles
Telemonitoring	21	[37,39,40,44–46,49,50,53,63,70,73,73,76–78,81,84,87,88,95]
Teleconsultation	14	[38,38,42,48,66,72,79,85,86,89,91,93,94,96]
Telesurgery	17	[43,47,52,54–62,69,74,75,82,92]
Tele-education	8	[46,59,64,64,65,68,83,90]
Telediagnosis	6	[41,51,65,67,71,80]

4.6. Related Articles

Other systematic review studies conducted [98] on deep learning assessed 200 articles from the ACM Digital Library, Science Direct, Springer Library, IEEE Xplore, PubMed, JMIR, and arXiv databases [98]. After eliminating irrelevant and repetitive articles, 67 articles were selected for the systematic literature review. From this, they were identified for analysis through 3 layers: physical medium, network, and application. These allowed a better quality when applying the use of federated learning in order to improve medical care [98]. Another systematic review [99] on mHealth applications used for identification and treatment of medical care used in eHealth used Scopus, ACM Digital Library, IEEE Xplore, Springer Link, PubMed, and Scopus databases [99]. A total of 250 articles relevant to the systematization of the literature were identified and it was concluded that there can be no single method to ensure the safety of all eHealth systems [99]. Furthermore, it was indicated that future research should be based on three factors: standardization of eHealth architectures, development of a unified architecture, and "improvement of blockchain technologies to improve security performance.

5. Conclusions

The tools or technologies that enable better medical care are based on cloud computing, artificial intelligence, the internet of medical things, blockchain technology, big data, and automatic learning. Similarly, most of the authors of the articles reviewed, rely on one parameter to produce their articles focused on the promptness of medical care. Thus, it stands out that most authors rely on the parameter ehealth care because they can observe and monitor online care and even take the study where the technology is available and applicable. The countries with the most projects implemented in the last 5 years were Germany, the United States, Italy, and Spain. Telesurgery, remote monitoring, mobile ultrasound, and biosensor technology were the most widely used in health care using applications based on 5G technologies.

The results of this systematic review are useful for future research looking for and learning about 5G-based technologies that facilitate monitoring and tracking for better healthcare, enabling the transformation of healthcare systems to be smarter, more efficient, and sustainable. The implementation of 5G technology is being deployed on a large scale worldwide, hence the importance of continuing to analyze new studies, exclusively of implementation where the 5G network improves medical care and the quality of health care.

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