# Mapping Digital Technologies in Healthcare: Analysis of Highly Cited Papers

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## Abstract

**Background:** The rapid development of digital technologies has produced a broad and heterogeneous body of healthcare related research. Mapping its most influential contributions is necessary to understand which technologies, applications, and user-related issues have shaped this field. **Objectives:** The main objective of the study is to map the digital technologies represented in highly cited research within the healthcare sector and the 2015–2025 search period. It also examines the field's development, citation impact, collaboration patterns, intellectual structure, and principal thematic areas. **Methods/Approach:** We identified 506 highly cited papers using a Web of Science Core Collection search. After title and abstract screening, we analysed 388 papers using citation indicators and VOSviewer. **Results:** The results revealed that artificial intelligence, telemedicine, the Internet of Things and smart healthcare, electronic health records, mobile health, wearable technologies, and conversational agents dominate the field. The analysis also identified themes related to integration, privacy, security, access, adoption, trust, literacy, and equity. **Conclusions:** Digital technologies in healthcare should be examined not only by type, but also by their use, implementation, and user experience. The findings provide a basis for further research on digital healthcare services and the experiences of patients and healthcare professionals in Croatia.

**Keywords:** digital technologies; healthcare; bibliometric analysis; topic analysis; literature review; highly cited papers

**JEL classification:** I10, M15, O33
**Paper type:** Research article

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# Introduction

The rapid development of digital technologies has opened numerous new possibilities for their application in medicine and healthcare. As these technologies have become more advanced and widely available, they have also been used more widely in healthcare, including diagnosis, treatment, patient monitoring, communication, and healthcare management (Meskó et al., 2017; Senbekov et al., 2020; Topol, 2019). This growing interest has produced a large, heterogeneous body of research across different technologies, applications, healthcare settings, and user groups. Therefore, mapping the most influential publications is important for obtaining a clearer overview of the field. This analysis can help identify which technologies have received the most research attention, how they have been applied in healthcare, and which user-related issues have influenced the field's development.

Digital technologies nowadays support and facilitate numerous activities across the healthcare sector. Their applications range from population-level surveillance and patient communication to clinical decision support, remote care, electronic health records, connected devices, and research data infrastructures. However, digital health is not limited to introducing and using individual technological tools. It also involves changes to work procedures, professional responsibilities, patient involvement, data governance, and the general structure of healthcare services. In that sense, the World Health Organisation (2025) groups technical, organisational, human, and financial resources within the same strategic framework for strengthening health systems.

Research has shown that operational efficiency, patient-centred methods, organisational characteristics, worker practices, and larger socio-economic situations are all interrelated in the digital transformation of healthcare (Kraus et al., 2021), which is in line with the general understanding of digital transformation as a process in which the usage of digital technologies leads to changes in organisational value creation, structures, and practices (Vial, 2019). However, the healthcare sector's broad scope has produced a rapidly growing body of literature spanning medicine, public health, informatics, engineering, management, education, and the social sciences. Therefore, it is difficult to describe and understand the entire field from the perspective of only one technology, clinical speciality, or scientific discipline.

Research on implementing digital health technologies also confirms that focusing only on technology is not sufficient. Clinical workflows, available organisational resources, professional perceptions, technology usability, and the extent to which different users participate in design and evaluation influence adoption (Bitkina et al., 2020; Slevin et al., 2020). Moreover, Pereira et al. (2023) argue that a patient-centred approach requires aligning internal processes, professional training, infrastructure, information provision, and co-creation with healthcare service users. Nevertheless, these relationships are often examined in the context of individual technologies, medical conditions, or user groups. As a result, it is difficult to connect the broader landscape of digital technologies with organisational readiness and users' experiences.

Considering the broad and multidisciplinary nature of this research area, bibliometric analysis represents an appropriate method for examining its development. It combines performance indicators with science-mapping techniques that reveal the intellectual, social, and conceptual relationships within a research field (Donthu et al., 2021). In addition, thematic mapping offers a complementary perspective by showing which digital technologies and healthcare applications frequently co-occur, how research topics are grouped, and which topics have emerged more recently. Focusing on Highly Cited Papers provides a selective

overview of research that has achieved exceptional citation impact within its field and year of publication. However, interpret citation-based selection carefully, since a publication's visibility and citation practices within individual disciplines do not necessarily reflect its clinical quality or broader societal value.

Although previous reviews have examined digital transformation in healthcare and the application of individual technologies, an integrated map of the most influential publications across the wider digital healthcare field is still needed. This study is the first analytical step of the "Digital Technologies and User Experience in the Healthcare Sector of the Republic of Croatia – DIGIZ" project, financed by the European Union's NextGenerationEU under Call IIP-581-2025, and provides a global evidence base for subsequent empirical activities. These activities will examine the digital presence of healthcare organisations through websites, mobile applications, and social media, as well as the experiences of patients and healthcare professionals in Croatia. The present study does not directly assess the digital readiness of Croatian healthcare organisations or the experiences of their users. Instead, it identifies the main technologies, healthcare applications, and implementation-related dimensions that should guide the later stages of the project.

With this in mind, this paper aims to map the development, impact, collaboration structure, intellectual base, and thematic organisation of highly cited research on digital technologies in healthcare. In order to fulfil the stated aim, the following research questions are addressed:

- RQ1: How did the publication output and citation impact of highly cited research on digital technologies in healthcare develop during the observed period?
- RQ2: Which publications and sources are the most influential, and which countries and organisations are the most prominent within the final sample?
- RQ3: How are international and interorganizational research collaboration networks structured?
- RQ4: Which sources constitute the main research fronts, and which cited references form the intellectual base of the field?
- RQ5: Which digital technologies dominate highly cited healthcare research, how are they connected with clinical, social, and implementation-related themes, and how have these thematic emphases developed over time?

To fulfil the stated aim and answer the research questions, the rest of the paper is structured as follows. The next section explains the data source, search strategy, screening process, selected indicators, and bibliometric procedures. The results are then presented through descriptive, citation, collaboration, co-citation, bibliographic coupling, keyword, and title-and-abstract analyses. Finally, the findings are discussed in relation to the stated research questions, followed by the research limitations, conclusions, and directions for future research.

# Methodology

## *Study design and search strategy*

To fulfil the stated aim and answer the research questions, this study conducted a bibliometric and thematic analysis. The general research design followed the performance-analysis and science-mapping approach described by Donthu et al. (2021), while the search for the highly cited papers analysed in this study has been conducted following the methodology employed by Usenik et al. (2026), which has been slightly modified. In that sense, the Web of Science Core Collection, without applying restrictions to individual citation indexes, served as the data source. The

analysis was limited to papers published in English and classified as Article, Review Article, or Proceedings Paper, published between 2015 and 2025.

The search for the Highly Cited Papers analysed in this study has been conducted on June 29, 2026 using the following query built through Query Builder: "*TS=("digital health" OR "digital healthcare" OR "digital health care" OR "digital medicine" OR ehealth OR "e-health" OR "health informatics" OR "medical informatics" OR "smart health" OR "smart healthcare" OR "smart health care" OR "smart hospital*" OR "connected health" OR "health 4.0" OR "healthcare 4.0" OR "health care 4.0" OR "hospital 4.0" OR "health 5.0" OR "healthcare 5.0" OR "health care 5.0" OR "hospital 5.0" OR (("digital technolog*" OR "digital transformation*" OR "digital innovation*" OR "digital solution*" OR "digital tool*" OR "digital platform*" OR "digital system*" OR "digital infrastructure*" OR "digital service*" OR "digital care" OR "technology-enabled care" OR "technology enabled care" OR "digitally enabled care" OR "information and communication technolog*" OR digitali?ation* OR digiti?ation*) NEAR/10 (healthcare OR "health care" OR "health system*" OR "health service*" OR hospital* OR clinic* OR clinical OR patient* OR medical OR medicine OR "public health" OR "primary care" OR "health professional*" OR "healthcare professional*" OR "health care professional*")))*". The search strategy comprised two conceptual blocks. The first block included well-known umbrella terms referring to the field of digital health. The second block combined general digitalisation-related terms with healthcare-related terms by using the NEAR/10 proximity operator. This approach enabled identification of individual technologies through subsequent bibliometric and thematic analyses, rather than defining them in advance by directly including them in the search query.

The search yielded 74,534 records. After applying filters for publication period, language, and document type, 51,857 records remained for analysis; after applying the Highly Cited Papers filter, 506 papers were included for title and abstract screening.

## *Eligibility criteria and screening*

Both authors individually screened all 506 identified Highly Cited Papers' titles and abstracts against three defined inclusion criteria. The inclusion criteria were the following: (i) the paper handles a specific digital technology, infrastructure, device or digitally enabled service; (ii) a certain digital technology is the central theme of the paper, and not just mentioned in passing; and (iii) the paper describes a clear application in healthcare, clinical practice, public health, healthcare management, healthcare workforce or medical education. Papers in which the digital concept is secondary, the technology is applied outside healthcare, those that present a general computational or engineering method without a specific healthcare application, or those that address a clinical/public health topic without a central digital technology component were excluded.

When the title and abstract were insufficient to assess a paper's eligibility, authors also reviewed its keywords and, if needed, the full text. The authors then compared the initial screening decisions and resolved all conflicts by collaboratively evaluating the relevant material until they reached agreement.

After screening, 388 papers (76.7%) were included in the final sample, while 118 papers (23.3%) were excluded. Recorded reasons for exclusion included non-health-domain false positives (n=29), general computing or engineering papers without a specific healthcare application (n=32), clinical or public-health papers without a central digital technology (n=54), and technology as an exposure or broad information context (n=3).

Table 1 summarises the study selection and screening process. We used relevant PRISMA 2020 reporting principles to describe the identification, screening, exclusion, and final inclusion of papers (Page et al., 2021). Because this study is a bibliometric analysis rather than a systematic review, we applied only the PRISMA items relevant to the paper selection process.

*Table 1*
Study selection and screening outcome

| Stage | Records | Outcome |
|---|---|---|
| **Topic search** | 74,534 | Eligible for year, language and document-type filters |
| **Topic search after year, language, and document-type filters** | 51,857 | Eligible for Highly Cited Papers filter |
| **Web of Science Highly Cited Papers** | 506 | Title-and-abstract screening |
| **Excluded after screening** | 118 | 23.3% of screened records |
| **Included in bibliometric and thematic analyses** | 388 | Final analytical corpus |

*Source:* Authors' work (2026)

## *Data extraction and analysis*

We exported full records and cited references for all 388 papers included in the analysis in plain-text format. We used Web of Science Analysis Results and the Citation Report to obtain data on publication years, document types, sources, authors, affiliations, countries or regions, research areas, Web of Science categories, and open-access status. The analysis also included total citations, citations excluding self-citations, citing articles, average citations per paper, and the h-index. Because Web of Science citation counts are continuously updated, all aggregate citation indicators reported in this study reflect the Citation Report values available on the date of data export (Clarivate, n.d.).

VOSviewer version 1.6.21 was used to construct and visualise the bibliometric networks. The software uses a visualisation-of-similarities approach to map bibliometric relationships (van Eck & Waltman, 2010), and its clustering procedure groups items by their relatedness within the network (Waltman et al., 2010).

The primary thematic map was based on co-occurring author keywords, full counting, and a minimum threshold of three occurrences. We created an additional map using a five-occurrence threshold as a robustness check. We analysed country and organisational co-authorship networks using fractional counting to reduce the excessive influence of papers with many authors. We used full counting for source-level bibliographic coupling and cited-reference co-citation analyses.

We used thesaurus files and manual inspection to combine spelling variants, abbreviations, and selected labels without changing the meaning of the analysed concepts. Table 2 provides an overview of the counting methods, thresholds, and resulting network sizes for all VOSviewer analyses.

Finally, we also created a text-based co-occurrence map using terms extracted from paper titles and abstracts. We used binary counting, meaning we counted each term only once within an individual paper. We considered terms occurring at least 20 times, then retained the 60% most relevant terms, following VOSviewer's default recommendation. Thesaurus-based normalisation and manual removal of general methodological and bibliographic terms left a final map with 41 terms. To improve figure readability, we displayed only the 300 strongest links, while retaining all 791 links in the saved network. We interpreted the clusters based on their most frequent and most strongly connected terms.

*Table 2*
Summary of VOSviewer analyses and network parameters

| Analysis | Counting | Threshold | Items | Clusters | Links | Total Link Strength |
|---|---|---|---|---|---|---|
| **Author-keyword co-occurrence (primary)** | Full | >=3 occurrences | 102 | 9 | 780 | 1,412 |
| **Author-keyword robustness map** | Full | >=5 occurrences | 55 | 5 | 414 | 927 |
| **Country co-authorship** | Fractional | >=5 documents | 33 | 5 | 352 | 271 |
| **Organisation co-authorship** | Fractional | >=5 documents | 34 connected* | 7 | 174 | 94.50 |
| **Source bibliographic coupling** | Full | >=3 documents | 29 | 5 | 243 | 2,320 |
| **Cited-reference co-citation** | Full | >=7 citations | 55 | 5 | 309 | 623 |
| **Title/abstract term co-occurrence** | Binary | >=20; top 60% relevance | 41 | 3 | 791 | 6,461 |

*Note:* *35 organisations met the threshold; the largest connected component contained 34 organisations and was used for visualisation
*Source:* Authors' work (2026)

# Results

## *Publication and Citation Profile*

First, we examined the publication and citation profile. In that sense, Figure 1 presents the annual publication output and citations for the final 388-paper sample. Although the observed period was 2015 to 2025, the final sample of 388 Highly Cited Papers that passed the title and abstract screening included papers published between 2016 and 2025, since no paper from 2015 remained after the screening process.

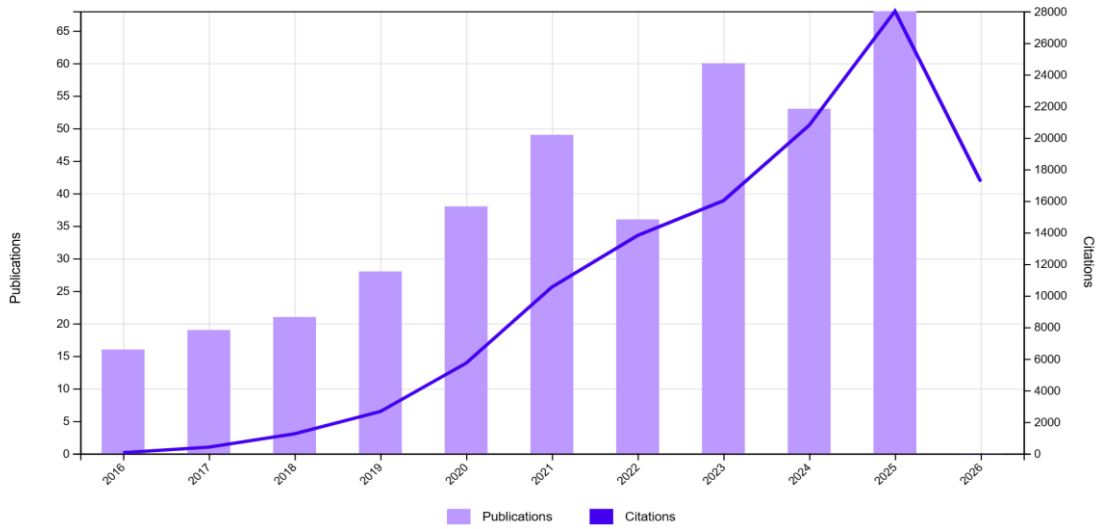
The annual number of Highly Cited Papers increased from 16 in 2016 to 68 in 2025. The highest numbers of published papers were recorded in 2025 (n = 68), 2023 (n = 60), and 2024 (n = 53), showing that highly cited research in digital technology and healthcare increased considerably in the later years of the observed period. The annual numbers for the remaining years were 19 papers in 2017, 21 in 2018, 28 in 2019, 38 in 2020, 49 in 2021, and 36 in 2022. Overall, 181 papers, representing 46.6% of the final sample, were published during the last three years of the observed period, indicating that Highly Cited Papers addressing digital technologies in healthcare were particularly strongly represented in the more recent part of the analysed period.

The citation trend, also visible in Figure 1, increased considerably over time, particularly from 2020 onwards. The citation line in Figure 1 reflects the number of citations received by the examined publications in the calendar year, not citations to papers published in that year.

According to the Web of Science Citation Report, the papers received 116,522 citations in total and 116,054 citations after excluding self-citations. They were cited by 96,408 articles, or 96,206 articles after excluding self-citations. The average number of citations per paper was 300.31, while the h-index was 198. The relatively small difference between the indicators with and without self-citations indicates that self-citations had only a limited impact on the overall citation profile. The results also

confirm the high scientific impact of the analysed papers, as expected, since the initial search included only papers listed as Highly Cited Papers in Web of Science.

*Figure 1*
Annual publication output and citations for the final 388-paper sample




*Note: Citations recorded in 2026 are included because the Citation Report was generated in 2026, but the value for 2026 represents only a partial year and should not be directly compared with the values for complete calendar years*
*Source:* Authors' work using Web of Science Citation Report tool (2026)

Regarding document types, 206 papers (53.1%) were classified as articles and 182 (46.9%) as review articles. Web of Science also assigned the Book Chapter label to three papers and the Early Access label to two papers; these overlapping metadata labels do not represent additional documents or changes to the document-type restrictions applied during the search.

Most of the analysed papers were openly accessible. A total of 309 papers (79.6%) were classified as open access, while 79 papers (20.4%) did not have an open-access designation in Web of Science.

The distribution across research areas further showed the interdisciplinary character of the analysed papers. The most frequent areas were Health Care Sciences and Services (n = 117; 30.2%), Medical Informatics (n = 112; 28.9%), Computer Science (n = 75; 19.3%), Public, Environmental and Occupational Health (n = 49; 12.6%), and Engineering (n = 32; 8.2%). Since Web of Science may assign a paper to more than one research area, these values are not mutually exclusive. The results show that research on digital technologies in healthcare combines health-service and medical-informatics perspectives with computer science, engineering, and public-health research.

## *Most influential publications*

The results revealed that citation impact was strongly concentrated among a small number of publications. The most cited paper was Harris et al. (2019), which presented the REDCap consortium and its international community of software-platform partners and received 14,299 citations in the fixed record-level export. It was followed by the paper on federated learning in digital health by Rieke et al. (2020) with 1,953 citations, systematic review of ChatGPT in healthcare education, research, and practice by Sallam (2023) with 1,726 citations, the randomized trial of the Woebot conversational

agent by Fitzpatrick et al. (2017) with 1,479 citations, and the study of telehealth during the COVID-19 pandemic by Smith et al. (2020) with 1,261 citations.

The ten most cited papers, presented in Table 3, also demonstrate the diversity of the digital healthcare field. Their topics include research data infrastructure, privacy-preserving machine learning, large language models, conversational agents, telehealth, wearable devices for monitoring vital signs, deep learning in health informatics, machine learning for clinical prediction, and medical computer vision. In this sense, the most influential research includes both widely reusable digital infrastructures and applications developed for specific clinical or patient-related purposes.

*Table 3*
Ten most cited papers in the final 388 Highly Cited Papers sample

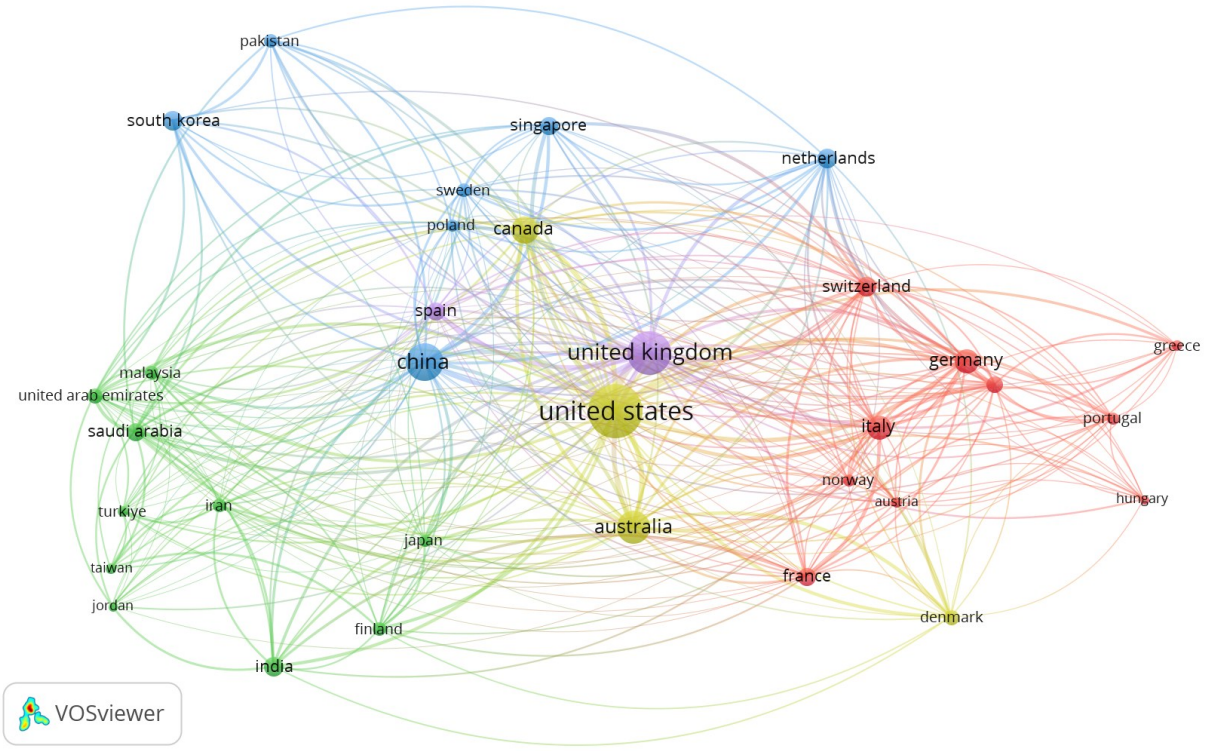
| No. | Authors | Paper title | Primary digital-health focus | Citations |
|---|---|---|---|---|
| 1 | Harris et al. (2019) | The REDCap consortium: Building an international community of software platform partners | REDCap research data platform | 14,299 |
| 2 | Rieke et al. (2020) | The future of digital health with federated learning | Federated learning and privacy | 1,953 |
| 3 | Sallam (2023) | ChatGPT Utility in Healthcare Education, Research, and Practice: Systematic Review on the Promising Perspectives and Valid Concerns | ChatGPT in education, research, and practice | 1,726 |
| 4 | Fitzpatrick et al. (2017) | Delivering Cognitive Behavior Therapy to Young Adults With Symptoms of Depression and Anxiety Using a Fully Automated Conversational Agent (Woebot): A Randomized Controlled Trial | Woebot conversational agent for mental health | 1,479 |
| 5 | Smith et al. (2020) | Telehealth for global emergencies: Implications for coronavirus disease 2019 (COVID-19) | Telehealth in COVID-19 emergencies | 1,261 |
| 6 | Khan et al. (2016) | Monitoring of Vital Signs with Flexible and Wearable Medical Devices | Wearable vital-sign monitoring | 1,213 |
| 7 | Ravi et al. (2017) | Deep Learning for Health Informatics | Deep learning for health informatics | 1,203 |
| 8 | Laranjo et al. (2018) | Conversational agents in healthcare: a systematic review | Conversational agents in healthcare | 880 |
| 9 | Sidey-Gibbons et al. (2019) | Machine learning in medicine: a practical introduction | Machine learning in medicine | 868 |
| 10 | Esteva et al. (2021) | Deep learning-enabled medical computer vision | Deep-learning medical computer vision | 863 |

*Note:* citation counts are taken from the Times Cited field in the fixed final Web of Science export and may change as the database is updated
*Source:* Authors' work (2026)

## *Geographic and institutional collaboration*

Further analysis revealed that authors of the 388 papers were affiliated with institutions in 72 countries or regions. Among them, 33 countries met the threshold of at least five papers and were included in the country co-authorship analysis. The results of that analysis are shown in Figure 2.

*Figure 2*
Country co-authorship network

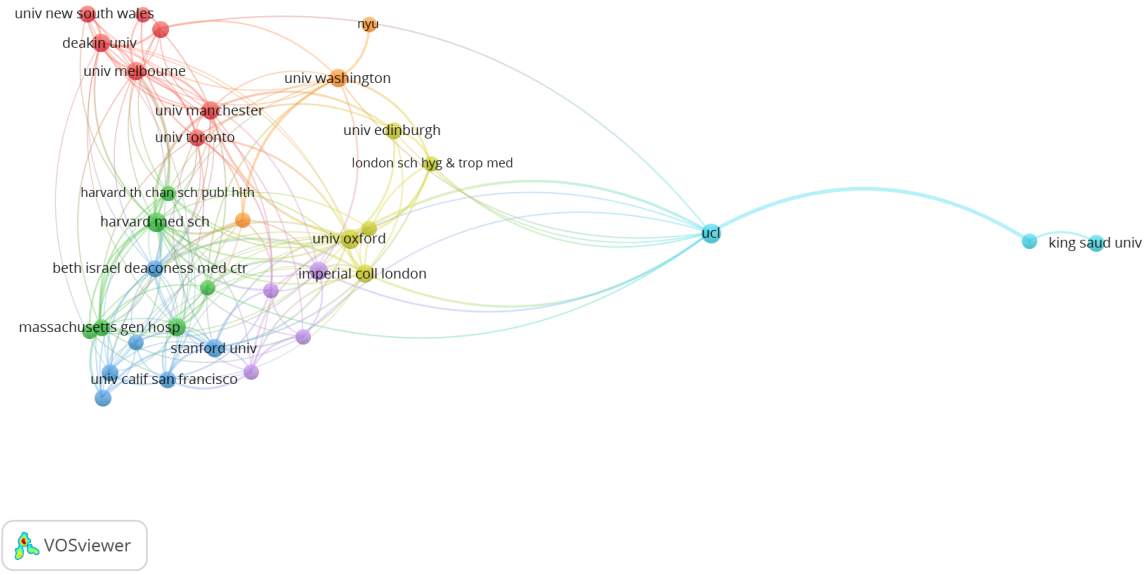



*Note:* fractional counting; minimum of five documents
*Source:* Authors' work using VOSviewer (2026)

The United States had the most papers (n = 143), followed by the United Kingdom (n = 92), China (n = 69), Australia (n = 54), and Canada (n = 36). These countries also received the most citations. The United States received 57,907 citations, followed by the United Kingdom (29,667), Australia (16,598), China (13,122), and Canada (9,842). The final country network consisted of five clusters, 352 links, and a fractional total link strength of 271, indicating strong international research collaboration.

At the organisational level, as presented in Figure 3, 35 institutions met the minimum threshold of five papers, of which 34 formed the largest connected component. Harvard Medical School had the most papers and the strongest collaboration position, with 19 papers, 6,981 citations, and a total link strength of 16. The University of Oxford followed with 18 papers, 6,599 citations, and a total link strength of 15. University College London (15 papers, 6,974 citations, total link strength 10) and Imperial College London (14 papers, 6,859 citations, total link strength 10) also held central positions in the network. The final institutional network consisted of seven clusters, 174 links, and a total link strength of 94.50. One institution met the defined threshold but had no co-authorship links with the largest connected component and was therefore not included in the network visualisation.

*Figure 3*
Organisation co-authorship network



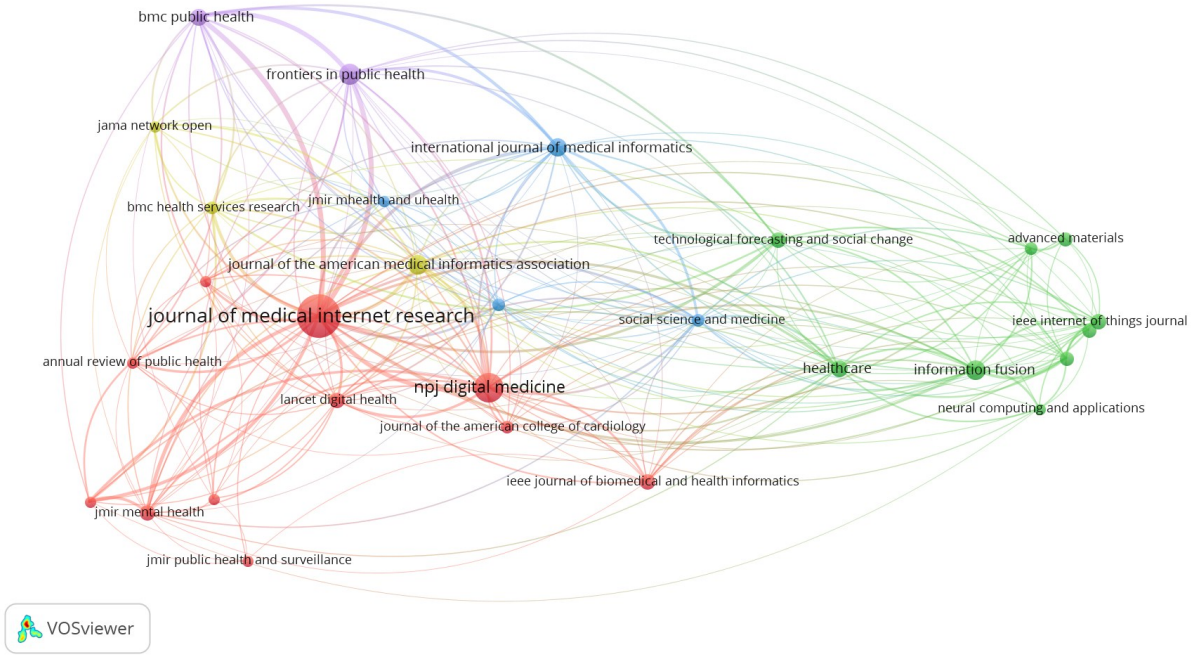

*Note:* fractional counting; minimum five documents; largest connected component
*Source:* Authors' work using VOSviewer (2026)

## *Publication sources and intellectual foundations*

The bibliographic-coupling analysis at the source level, presented in Figure 4, included 29 journals that published at least three papers. The final network contained 243 links and had a total link strength of 2,320. The Journal of Medical Internet Research was the leading source considering both the number of papers and its position in the network. It published 43 papers that received 11,201 citations and had a total link strength of 945. npj Digital Medicine followed with 20 papers, 6,852 citations, and a total link strength of 367. Other prominent sources were Frontiers in Public Health (11 papers; 952 citations; total link strength 387), Information Fusion (10 papers; 1,972 citations; total link strength 197), and the Journal of the American Medical Informatics Association (10 papers; 2,977 citations; total link strength 171). Although BMC Public Health published only seven papers, it had a total link strength of 411, which was the second-highest value in the network. This result shows that its papers shared many references with papers published in other journals included in the analysis.

The analysis resulted in five clusters. The first cluster mainly included digital-health journals and journals focused on clinical and behavioural research. The second consisted of engineering, computing, and materials-science journals, while the third connected medical informatics with education and social sciences. The fourth cluster included clinical informatics, health services, and related journals, and the fifth mainly consisted of public-health sources. The many connections between clusters show that highly cited research on digital technologies in healthcare draws on knowledge from several related research areas.

*Figure 4*
Source bibliographic-coupling network

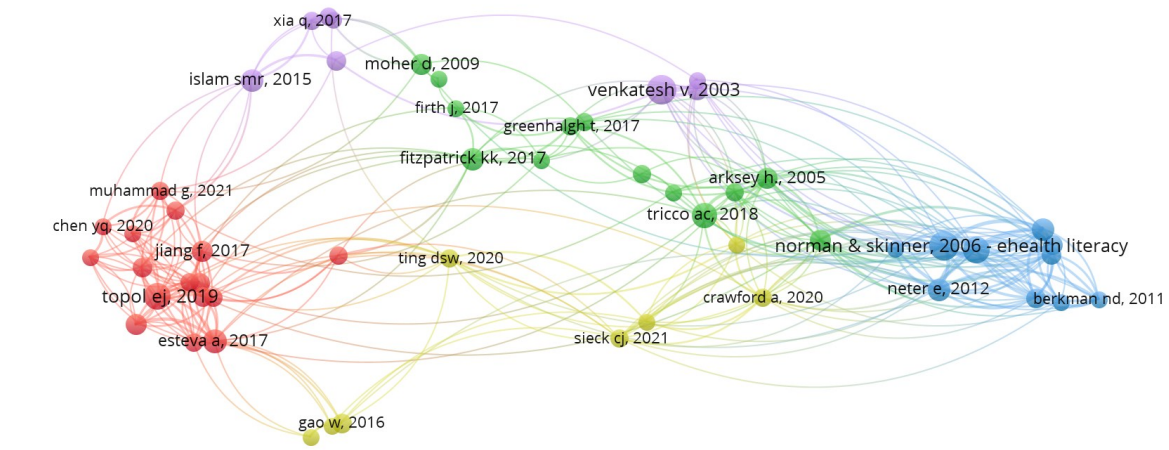



*Note:* full counting; minimum three documents
*Source:* Authors' work using VOSviewer (2026)

The cited-reference co-citation analysis included 55 references cited by at least seven papers from the final sample, as presented in Figure 5. The resulting network consisted of five clusters, 309 links, and a total link strength of 623. The references cited by the highest number of papers were the eHealth literacy framework developed by Norman et al. (2006 a) which was cited by 21 papers, the Unified Theory of Acceptance and Use of Technology (UTAUT) proposed by Venkatesh et al. (2003) and cited by 20 papers, research on high-performance medicine and artificial intelligence by Topol (2019), cited by 18 papers, and the eHEALS measure developed by Norman et al. (2006 b), cited by 17 papers.

The first cluster mainly included fundamental research on artificial intelligence, machine learning, medical imaging, explainable artificial intelligence, and federated learning. The second cluster combined methodological guidelines for conducting scoping and systematic reviews with research on digital and mobile mental-health interventions. The third cluster was focused on eHealth literacy, health literacy, digital access, and the eHEALS measure. The fourth cluster connected research on the digital divide and equal access with broader digital-health strategies and emerging healthcare technologies. Finally, the fifth cluster combined technology-acceptance research with studies on the Internet of Things, connected-health infrastructure, privacy, security, and distributed healthcare systems. The revealed clusters show that the field's intellectual foundations combine technical development and clinical applications with research methodology, digital literacy and access, technology acceptance, and implementation.

*Figure 5*
Cited-reference co-citation network




*Note:* full counting; minimum seven citations
*Source:* Authors' work using VOSviewer (2026)

## *Author-keyword thematic structure*

The primary author-keyword co-occurrence analysis included 102 keywords and resulted in nine clusters, 780 links, and a total link strength of 1,412.

Digital health was the most frequently used keyword, with 80 occurrences. It was followed by artificial intelligence (65 occurrences), eHealth (45 occurrences), mHealth (35 occurrences), machine learning (31 occurrences), telemedicine (29 occurrences), the Internet of Things (26 occurrences), deep learning (24 occurrences), and smart healthcare and mental health (22 occurrences each).

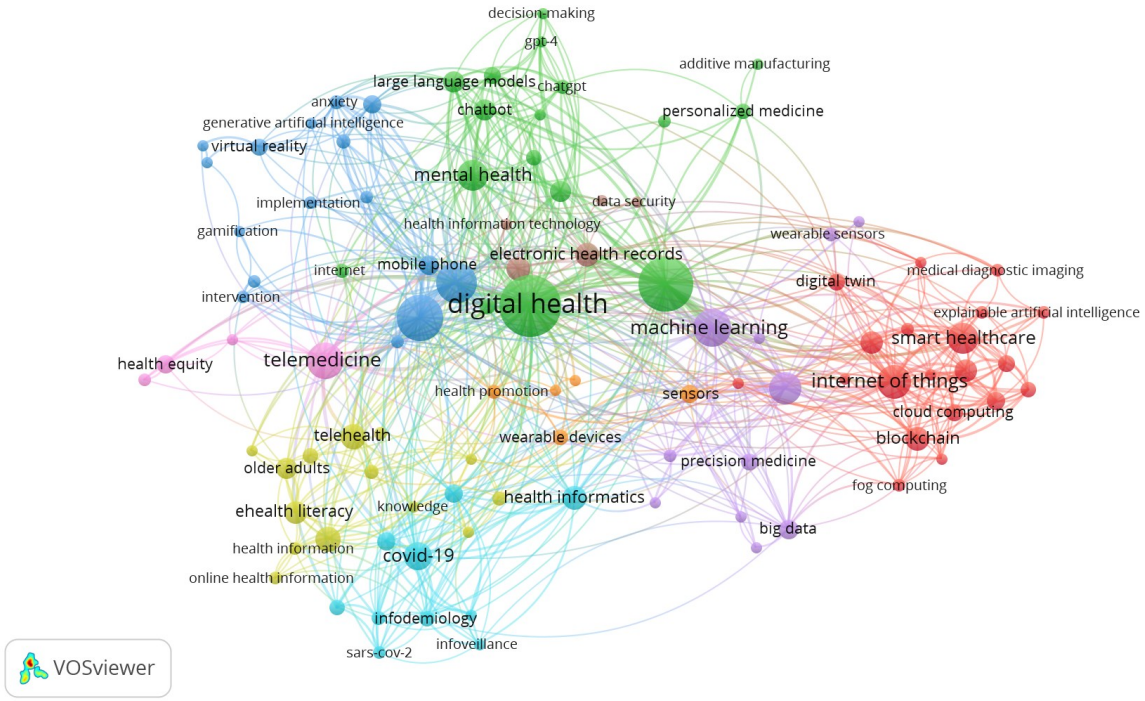
Figure 6 presents the author-keyword co-occurrence network, while Table 4 interprets the nine identified clusters and their leading keywords.

The largest and most central nodes show that digital health, artificial intelligence, eHealth, machine learning, telemedicine, and the Internet of Things formed the main thematic areas of the analysed research.

The network also shows that these areas were strongly interconnected. Digital health occupied a central position and connected technology-oriented themes with clinical, social, and implementation-related research.

As presented in Table 4, the first cluster focused on connected and smart healthcare, including the Internet of Things, blockchain, security, privacy, and the Internet of Medical Things. The second cluster connected digital health with artificial intelligence and conversational technologies. The remaining clusters covered mobile and immersive mental health; literacy, inclusion, and digital transformation; machine learning and precision medicine; pandemic and public-health informatics; wearable monitoring and health promotion; clinical information infrastructure; and telemedicine, equity, and health policy. These results show that mapping digital technologies in healthcare requires consideration of both technological solutions and the clinical and social settings in which they are developed and used.

*Figure 6*
Author-keyword co-occurrence network




*Note:* full counting; minimum three occurrences
*Source:* Authors' work using VOSviewer (2026)

*Table 4*
Interpretation of the nine author-keyword clusters

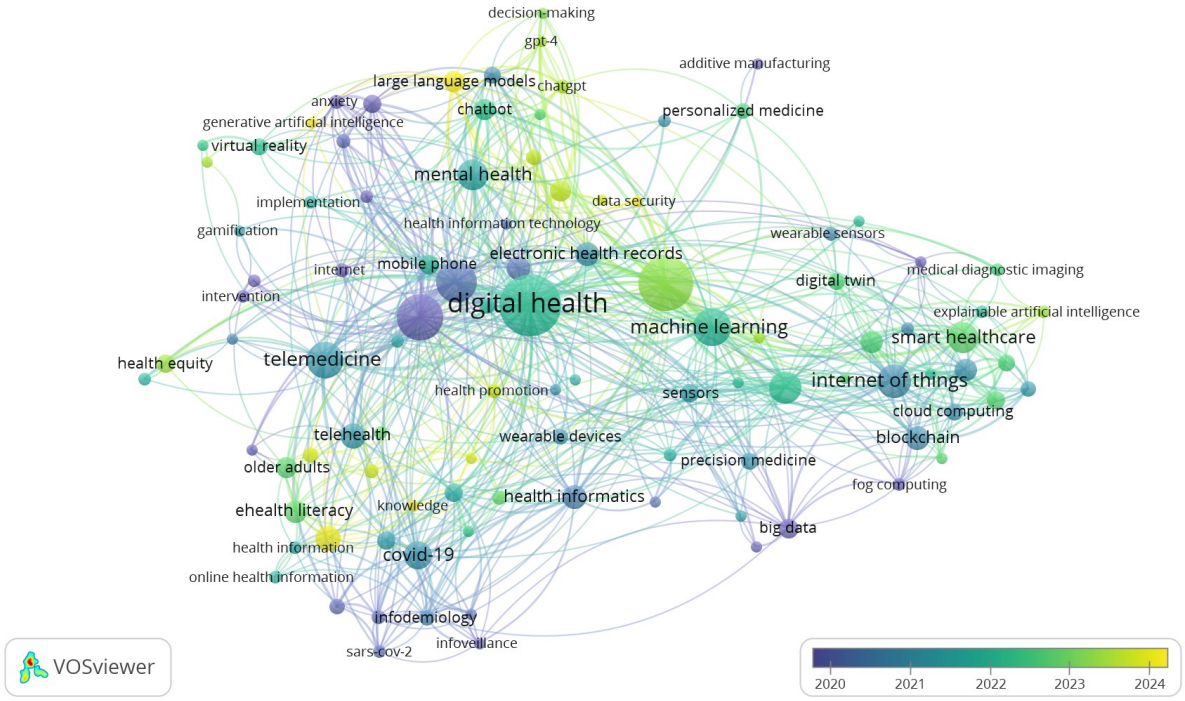
| No. | Interpretive label | Leading author keywords |
|---|---|---|
| 1 | Connected and smart healthcare | internet of things; smart healthcare; blockchain; security; privacy; internet of medical things |
| 2 | Digital health and conversational AI | digital health; artificial intelligence; mental health; natural language processing; large language models; chatbot |
| 3 | Mobile and immersive mental health | ehealth; mhealth; mobile phone; depression; virtual reality; engagement; anxiety |
| 4 | Literacy, inclusion, and transformation | telehealth; digital health literacy; ehealth literacy; older adults; digital divide; digital transformation |
| 5 | Machine learning and precision medicine | machine learning; deep learning; big data; precision medicine; wearable sensors; bioinformatics |
| 6 | Pandemic and public-health informatics | covid-19; health informatics; social media; public health; pandemic; infodemiology |
| 7 | Wearable monitoring and promotion | sensors; wearable devices; health promotion; smartwatch; atrial fibrillation |
| 8 | Clinical information infrastructure | medical informatics; electronic health records; health information technology; data security |
| 9 | Telemedicine, equity, and policy | telemedicine; health equity; social determinants of health; health policy |

*Source:* Authors' work (2026)

As shown in Figure 7, the average publication year of the keywords provides insight into how research topics have developed over time. Earlier research was more

frequently associated with telemedicine, eHealth, big data, blockchain, and pandemic-related topics. In contrast, more recent research was focused on large language models, ChatGPT, GPT-4, generative artificial intelligence, decision-making, data security, and explainable artificial intelligence. These results indicate that the research focus has gradually shifted from established digital-health infrastructure and remote-care technologies towards generative and conversational artificial intelligence and more advanced data-driven healthcare applications.

*Figure 7*
Author-keyword overlay visualisation by average publication year



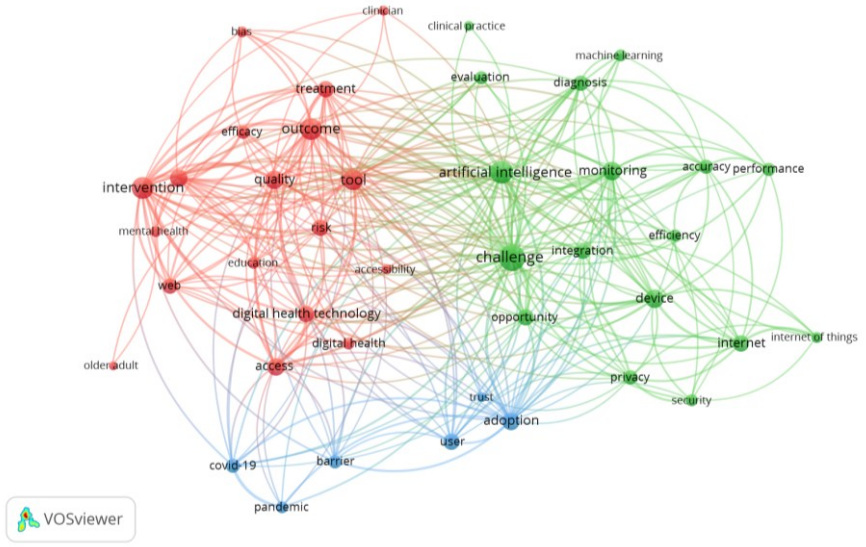

*Note:* full counting; minimum three occurrences; node colour indicates the average publication year
*Source:* Authors' work using VOSviewer (2026)

We conducted an additional robustness analysis using a minimum threshold of five occurrences. It retained 55 keywords and reproduced the main thematic areas identified in the primary analysis, although the smaller network resulted in five broader clusters. This supports the stability of the overall thematic interpretation.

## *Themes in titles and abstracts*

The co-occurrence analysis of title and abstract terms, as shown in Figure 8, retained 41 terms and produced three clusters, 791 links, and a total link strength of 6,461. The first cluster referred to clinical application and evaluation and included terms such as outcome, intervention, tool, quality, effectiveness, access, treatment, mental health, and clinical practice. The second cluster focused on technological capabilities and system integration and included terms such as challenge, artificial intelligence, device, monitoring, internet, opportunity, integration, diagnosis, accuracy, performance, privacy, and security. The third cluster dealt with implementation conditions and user responses, with adoption, user, barriers, trust, COVID-19, and pandemic as its leading terms.

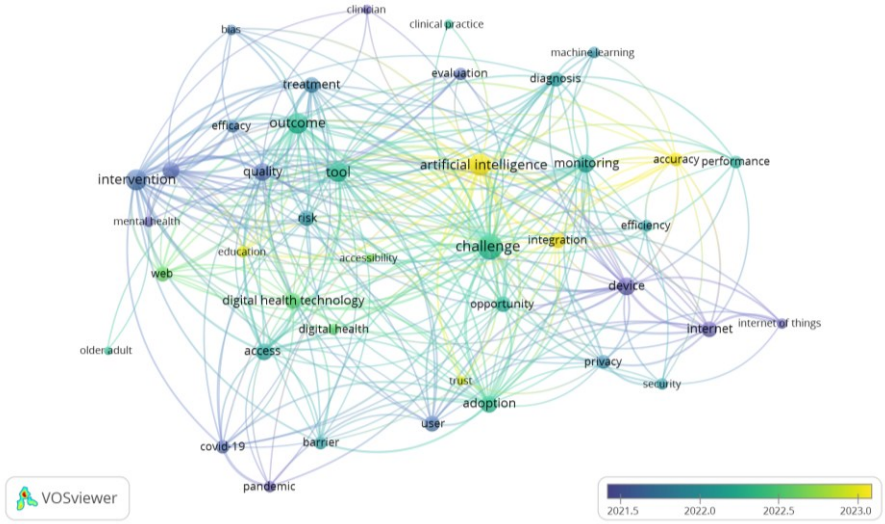
*Figure 8*
Title-and-abstract term co-occurrence network




*Note:* binary counting; minimum 20 occurrences; 60% most relevant terms
*Source:* Authors' work using VOSviewer (2026)

The overlay visualisation in Figure 9 indicates a shift from pandemic-related research, early intervention studies, and topics connected with devices and the internet toward artificial intelligence, diagnostic performance, system integration, and selected issues of access and education. However, this finding should be understood as a gradient based on average publication year, not as a causal sequence. Nevertheless, the results suggest that more recent highly cited papers increasingly connect artificial intelligence capabilities with questions of implementation and evaluation.

*Figure 9*
Overlay visualisation of title-and-abstract terms by average publication year




*Note:* binary counting; minimum 20 occurrences; 60% most relevant terms; node colour indicates the average publication year
*Source:* Authors' work using VOSviewer (2026)

## Discussion

In relation to RQ1, the findings indicate that highly referenced research on digital technology in healthcare grew significantly over the observed period. The number of publications in the final sample increased from 16 in 2016 to 68 in 2025. The final sample had 116,522 citations and an h-index of 198, suggesting a strong cumulative citation effect. However, these metrics represent the full final sample and are not meant to directly compare citation impact across specific publication years. At the same time, the mapping analysis indicates that highly cited research in this subject links several technology- and healthcare-related study topics.

The second research question referred to the most influential publications and sources, as well as the most prominent countries and organisations. The results revealed that citation impact was concentrated within a relatively small group of publications. The leading papers focused on research data infrastructures, federated learning, conversational agents, telehealth, wearable devices, health informatics, and medical computer vision (Esteva et al., 2021; Fitzpatrick et al., 2017; Harris et al., 2019; Khan et al., 2016; Ravi et al., 2017; Rieke et al., 2020; Sallam, 2023; Smith et al., 2020). In that sense, both widely applicable digital infrastructures and technologies developed for direct clinical or patient-related use achieved high citation impact. Among publication sources, the Journal of Medical Internet Research ranked first, while npj Digital Medicine, Frontiers in Public Health, Information Fusion, and the Journal of the American Medical Informatics Association were also among the most prominent. The United States and the United Kingdom had the highest publication output and citation impact, followed by China, Australia, and Canada as other main contributing countries. At the organisational level, Harvard Medical School, the University of Oxford, University College London, and Imperial College London were the most notable.

Regarding RQ3, the country network contained 352 links and showed that the United States and the United Kingdom held central positions. Both countries had research connections with countries from Europe, Asia, the Middle East, and the Asia-Pacific region. The organisational network consisted of seven clusters and contained 174 links. Most institutions formed a relatively dense central network, while some organisations occupied more peripheral positions and had fewer strong connections. The high number of links at both levels indicates that highly cited research on digital technologies in healthcare is characterised by strong international and interorganizational collaboration. However, differences in network positions and publication output show that participation remains uneven across countries and institutions.

The source bibliographic-coupling and cited-reference co-citation analyses answered RQ4. The Journal of Medical Internet Research and npj Digital Medicine were among the central publication sources forming the main research fronts. However, the network also included closely connected journals from public health, behavioural science, medical informatics, materials science, information systems, and engineering. In that sense, the current research fronts are not limited to healthcare-related publication sources but also include journals focused on different technological areas. The cited-reference co-citation map linked research on eHealth literacy and digital access with methodological guidelines and technical studies on artificial intelligence, medical imaging, technology acceptance, and distributed computing. The area's conceptual foundation therefore encompasses technological, therapeutic, methodological, and socio-behavioural viewpoints. This conclusion aligns with earlier research showing that digital transformation in healthcare comprises

operational, patient-centred, organisational, workforce, and socio-economic elements, not just technology (Kraus et al., 2021).

For RQ5, the study examined dominant digital technologies, their connections to clinical, social, and implementation-related themes, and their development over time. The author-keyword analysis revealed nine clusters focused on connected and smart healthcare, artificial intelligence and conversational technologies, mobile and mental health, digital literacy and equity, machine learning and precision medicine, pandemic informatics, wearable monitoring, clinical information infrastructure, and telemedicine. In contrast, analysing terms extracted from titles and abstracts grouped the field into three broader areas: clinical application and evaluation; technological capability and integration; and implementation, users, trust, and barriers. In that sense, the two analyses provided complementary findings. Author keywords identified specific technologies and established research topics, while the terms extracted from titles and abstracts revealed their connections with clinical outcomes, users, implementation conditions, and healthcare processes.

The overlay maps revealed additional changes in thematic emphasis during the observed period. Earlier research was more strongly associated with telemedicine, eHealth, big data, blockchain, pandemic response, and selected infrastructure-related technologies. More recent research was more frequently associated with large language models, ChatGPT, GPT-4, generative and explainable artificial intelligence, decision-making, data security, and diagnostic performance. However, the emergence of these technologies did not make the previously identified implementation problems less important. The increasing use of artificial intelligence and connected systems additionally emphasises issues related to privacy, bias, trust, clinical validation, accessibility, and organisational readiness.

The presented results also have theoretical and practical implications. From the theoretical perspective, they support the understanding of digital healthcare as a socio-technical transformation in which technologies, organisational arrangements, users, and value-creation processes develop together (Vial, 2019). From the practical perspective, the technical performance of a digital tool represents only one part of its value in healthcare. Its adoption and continued use also depend on how well patients and healthcare professionals understand the technology, how well it fits existing healthcare processes, the perceived trustworthiness and usefulness of its outputs, and whether different user groups have equal access.

In the context of the DIGIZ project, the presented findings indicate that future empirical research should connect individual technologies with user experience and implementation outcomes. The bibliometric maps identified several relationships to investigate further, including artificial intelligence and trust, telemedicine and access, digital literacy and equity, electronic health records and workflow integration, connected devices and privacy, and web- or social-media-based services and user engagement. These research directions align with previous findings that professional perceptions, workflows, and organisational resources influence implementation (Slevin et al., 2020). They are also consistent with research showing that patient-centred improvement requires adequate information, infrastructure, professional training, and co-creation with service users (Pereira et al., 2023).

# Conclusion

This paper aimed to map the development, impact, collaboration structure, intellectual base, and thematic organisation of highly cited digital healthcare research. To meet this aim, we screened 506 Highly Cited Papers from the Web of Science Core Collection. After applying the defined inclusion and exclusion criteria,

we included 388 papers in the descriptive, citation, collaboration, co-citation, bibliographic-coupling, author-keyword, and title-and-abstract analyses.

The results address five research questions. They show that highly cited digital healthcare research expanded strongly from 2016 to 2025 and that a considerable share of its citation impact is concentrated in widely reusable digital infrastructures and several prominent healthcare applications. The United States and the United Kingdom, together with a group of leading universities, occupy central positions within dense international and institutional collaboration networks. Moreover, the field's intellectual base connects medical informatics and digital medicine with public health, behavioural research, engineering, and information systems. Finally, the thematic maps reveal that artificial intelligence, telemedicine, connected devices, clinical information systems, digital literacy, equity, trust, privacy, and implementation belong to the same wider research landscape.

Although this study extends the existing body of knowledge, several limitations warrant consideration. First, the analysis is based on a single bibliographic database and includes only papers published in English. Therefore, relevant research indexed in other databases or published in other languages may not be represented. Second, the Highly Cited Papers category is normalised by research field and publication year, but it still relies on citations, making it an indicator of research publicity and impact, not methodological excellence, clinical efficacy, or social worth. Third, citation counts are continuously updated and may change after the final data export. Moreover, title- and abstract-based screening cannot fully replace full-text assessment of every borderline paper, although we consistently applied the same centrality and healthcare-application criteria. Finally, the identified bibliometric clusters depend on metadata quality, author terminology, counting methods, selected thresholds, and thesaurus decisions. Therefore, interpret network proximity and co-occurrence as relationships between concepts, not as evidence of causal or complete conceptual equivalence.

The main contribution of this paper is the integrated overview of digital technologies and their implementation conditions within a screened corpus of highly cited publications. For the DIGIZ project, the study provides a conceptual and empirical basis for connecting the identified technology and service landscape with the digital presence of healthcare organisations and the experiences of patients and healthcare professionals in Croatia. Although this study does not directly examine the digital maturity of Croatian healthcare organisations, it identifies possible dimensions of the planned Digital User Experience Index, including access, digital literacy, usefulness, trust, privacy, workflow fit, engagement, and equity. Having in mind the limitations related to the use of a single database, the English-language restriction, changing citation counts, and metadata-dependent clustering, future studies should compare the Web of Science results with Scopus or other relevant databases, observe thematic changes over shorter time periods, connect bibliometric themes with full-text content analysis, and empirically validate the proposed DIGIZ dimensions across different user groups and healthcare settings.

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