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THE ROLE OF ARTIFICIAL INTELLIGENCE IN PERSONALISED MEDICINE: ADVANCEMENTS, CHALLENGES, AND FUTURE PERSPECTIVES

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Abstract
Artificial Intelligence (AI) has emerged as a transformative technology in healthcare, significantly advancing personalised medicine. By leveraging vast amounts of data, AI enhances early disease detection, tailors treatments to individual patients, and optimises medical resource management. Despite these advantages, the integration of AI in healthcare presents challenges, including concerns over data privacy, acceptance among healthcare professionals, and the need for comprehensive regulatory frameworks. Therefore, this study investigates the impact of AI on personalised medicine, assessing its benefits, limitations, and real-world applications. It explores AI's role in diagnostics, personalised treatment strategies, and the optimisation of medical workflows, while critically examining ethical and legal challenges. The study also underscores the necessity of robust regulations to ensure responsible and ethical AI deployment in healthcare. A systematic documentary analysis of scientific articles, case studies, and healthcare organisation reports forms the basis of this research. Case studies from hospitals and companies that have successfully implemented AI are analysed to evaluate its impact on diagnostic accuracy, treatment efficiency, and medical costs. The findings are correlated with existing literature to provide a comprehensive perspective on current and future trends in AI-driven personalised medicine. The results of this study show that AI has demonstrated significant improvements in diagnostic precision, reduced the time required for disease identification, and enhanced the effectiveness of personalised treatment plans. Studies indicate that AI-driven approaches contribute to cost reductions by minimising late-stage treatments and enabling more efficient allocation of medical resources. However, critical challenges such as algorithm transparency, bias mitigation, and patient data security continue to hinder widespread AI adoption in healthcare.

Keywords: Artificial intelligence, AI in healthcare, Data privacy, Healthcare technology, Personalised medicine.
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1. INTRODUCTION

Personalised medicine is based on the premise that each individual has distinct genetic characteristics, necessitating the adaptation of treatments according to the patient's biological profile. Advances in artificial intelligence (AI) enable the sophisticated analysis of genomic data, thereby facilitating a more efficient and customised medical approach (Qayyum et al., 2023; Hampel et al., 2023). This innovative method is applied in disease prevention, early diagnosis, medication dosage adjustments, and the development of targeted therapies, contributing to improved clinical outcomes and a reduction in the side effects associated with standardised treatments (Shiwlani et al., 2024).

The transformation of personalised medicine is driven by continuous progress in genetics, artificial intelligence, and digital technologies. The concept of P4 medicine—predictive, preventive, personalised, and participatory—reflects this evolution and relies on the integration of complex biological data sets with advanced digital technologies to provide tailored medical solutions for each patient (Delpierre & Lefèvre, 2023).

However, large-scale implementation of personalised medicine poses significant challenges. Traditional disease classifications may require redefinition to incorporate this approach, and healthcare systems must adopt technological solutions capable of managing vast amounts of data (Hampel et al., 2023). Big data technologies allow for the consideration of inter-individual variability in clinical decision-making, leading to increased treatment efficacy and improved diagnostic accuracy. In this context, some European countries have begun adopting national strategies and investing in the necessary infrastructure to facilitate the integration of personalised medicine into their healthcare systems (Stenzinger et al., 2023).

Artificial intelligence plays a pivotal role in optimising medical processes, significantly impacting diagnostic accuracy, operational efficiency, and the economic sustainability of healthcare systems. With its ability to rapidly and accurately process large volumes of data, AI helps reduce the time required for disease identification, leading to faster and more effective interventions (Shiwlani et al., 2024; Qayyum et al., 2023).

Additionally, AI-powered medical devices enhance patient monitoring, allowing for the early detection of complications and enabling swift medical intervention when necessary (Delpierre & Lefèvre, 2023). AI also facilitates the development of personalised treatment plans by analysing individual patient data and using predictive models to recommend the most appropriate therapies (Rubinger et al., 2023).

Beyond clinical benefits, AI contributes to improving administrative and operational efficiency within medical institutions. The automation of routine tasks—such as appointment scheduling, documentation management, and resource allocation—allows healthcare professionals to focus more on patient care (Hampel et al., 2023). However, the widespread use of AI in healthcare also raises critical challenges, including the need for algorithm transparency, patient data protection, and addressing the ethical dilemmas associated with these technologies.

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2. LITERATURE REVIEW

2.1. Definition and applications of AI

Artificial Intelligence (AI) refers to the ability of technological systems to perform tasks that require human intelligence (Khan et al., 2023). In the medical sector, AI has advanced significantly, leveraging vast amounts of data and computational power to support diagnosis, enhance medical devices, and predict patient outcomes (Ali et al., 2023). However, the adoption of AI in healthcare has been relatively slow due to regulatory, organisational, and individual barriers (Apell & Eriksson, 2023).

The integration of digital technologies in medicine aims to optimise processes, improve patient care quality, and advance research, thereby contributing to the development of personalised medicine. By analysing large volumes of data, AI facilitates clinical decision-making and enhances the operational workflow of healthcare institutions (Patil & Shankar, 2023).

AI is utilised across various medical fields, from automating documentation and managing insurance processes to image analysis and complex data processing. It also plays a essential role in drug discovery and design, aiding in the identification of protein structures and their interactions (Shiwlani et al., 2024; Patil & Shankar, 2023; Qayyum et al., 2023).

A concrete example of AI's applicability in medicine is ChatGPT, which can assist healthcare professionals in updating their knowledge, assessing clinical competencies, and supporting the diagnostic process by analysing relevant data to provide precise information (Dave et al., 2023). Large language models (LLMs) are employed for patient interactions, medical text analysis and generation, electronic health record (EHR) management, medical education, treatment planning, and diagnosis (Zhou et al., 2023).

In medicine, machine learning algorithms play a essential role in disease diagnosis and prognosis, improving the accuracy of assessments and personalising therapeutic strategies. Predictive models analyse complex datasets and can identify subtle anomalies in medical imaging from the earliest stages of a disease (Rasool et al., 2023).

By detecting patterns and correlations in large datasets, AI enhances medical decision-making, facilitating the identification of new biomarkers and risk factors associated with various pathologies. As a result, this technology not only aids in early diagnosis but also supports the development of innovative therapies. Furthermore, AI enables the continuous monitoring of disease progression and treatment efficacy, allowing for rapid intervention in cases of relapse or treatment failure (Ramudu et al., 2023).

The combination of clinical expertise with machine learning algorithms enables medical professionals to predict disease progression and tailor treatments according to each patient's unique characteristics. This approach not only improves the quality of care but also optimises therapeutic strategies (Mohsin et al., 2023; Li et al., 2024).

Machine learning is not limited to diagnosis; it also plays a significant role in anticipating disease progression, allowing for early and personalised interventions. Early detection and appropriate treatment administration reduce both the physical impact on patients and the financial burden on healthcare systems. Furthermore, AI's ability to rapidly process vast amounts of data provides a significant advantage in addressing the shortage of medical personnel, supporting clinical decision-making and resource management.

AI-powered personalised therapy allows treatments to be tailored to each patient's individual characteristics. This innovative approach has the potential to transform healthcare by providing more precise and effective solutions. In addition to improving therapeutic outcomes, personalising treatments optimises the use of medical resources, reducing both costs and waste.

A key aspect of personalised therapy is data-driven treatment recommendations, which enhance treatment efficacy and minimise adverse effects (Chaudhary et al., 2023).

One important element in this field is the human microbiome, the collection of microorganisms that inhabit the human body. The microbiome influences individual responses to treatments and helps explain variability in disease manifestation, even among patients with similar genetic backgrounds. Consequently, microbiome modulation is emerging as a promising strategy for adapting therapeutic interventions to individual patient needs (Ratiner et al., 2024).

Clinical studies indicate that personalised therapy yields superior results compared to standardised treatments (Nye, Delgadillo & Barkham, 2023). Additionally, the use of pharmacogenomic data enables the prediction of adverse reactions and the adjustment of dosages, contributing to optimised treatment plans for each patient (Thimmaraju et al., 2024).

AI-driven robotic technologies and virtual assistants have become integral to the automation of healthcare processes, enhancing operational efficiency, reducing costs, and alleviating the workload of medical staff while ensuring continuity of care throughout the therapeutic process.

The integration of robotics in medicine offers numerous benefits. For example, in surgery, robotic systems enable procedures to be performed with greater precision, minimising incision size and accelerating patient recovery (Kaur, 2023). Medical robots are also used in rehabilitation, assisting patients in regaining mobility and motor functions.

On the other hand, virtual assistants, equipped with Natural Language Processing (NLP) technologies, facilitate interactions between patients and healthcare systems, efficiently managing communication and treatment organisation. These intelligent systems not only optimise information flow but also provide emotional support to patients, reducing stress and anxiety associated with illness (Giachos et al., 2023).

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Moreover, robotic systems play an essential role in hospital administration and logistics, assisting with documentation management and patient flow coordination. They help reduce human errors and minimise infection transmission risks by limiting direct contact. By automating these tasks, medical professionals can focus on essential healthcare activities, improving both quality of care and patient safety.

2.2. Personalised medicine: a new model of care

The concept of personalised medicine, first introduced by Gibson in 1971, has evolved significantly, becoming closely linked to the development of pharmacogenomics (Pokorska-Bocci et al., 2014). The fundamental principles of this field include genetic profiling, personalised treatment administration, predictive analysis, and real-time patient monitoring (Obijuru et al., 2024). This approach extends beyond biological factors, considering each patient's living conditions to ensure more precise and tailored care.

An emerging direction in personalised medicine focuses on the use of biomarkers to optimise early screening strategies, identify specific pathophysiological signatures, and develop targeted therapies tailored to individual patient characteristics. This innovative approach not only enhances healthcare quality but also significantly reduces treatment-related costs.

Personalised medicine has a profound impact across various medical fields, including oncology, rare disease treatment, and pharmacogenomics, contributing to optimised therapy and increased treatment efficacy (Cellina et al., 2023).

In oncology, personalised medicine employs genetic testing to guide therapy selection, enabling the customisation of treatments based on the specific genetic characteristics of each cancer type (Qayyum et al., 2023). Genetic profiling of tumours facilitates the identification of clinically relevant mutations, such as EGFR mutations in non-small cell lung cancer, which can be effectively treated with specific inhibitors like gefitinib or erlotinib. Similarly, the BRAF V600 mutation, commonly found in melanoma, can be targeted using BRAF inhibitors, such as vemurafenib or dabrafenib (Dash et al., 2024).

Advances in neuroscience have enabled the identification of specific pathophysiological signatures associated with neurological and psychiatric disorders, facilitating early diagnosis and patient stratification into biologically distinct subgroups (Hampel et al., 2023). Studies indicate that AI-driven personalised therapies, which tailor treatments to individual patients based on predictive algorithms, can yield superior outcomes compared to current standardised approaches (Nye, Delgadillo & Barkham, 2023; Qayyum et al., 2023).

The diagnosis and treatment of rare diseases have been greatly improved through personalised medicine, which enables the identification of genetic mutations responsible for these conditions. This approach supports the development of targeted therapies that directly address the genetic causes of diseases, significantly enhancing treatment effectiveness. Since many rare diseases have well-defined genetic foundations, personalised medicine plays a critical role in accelerating diagnosis and designing customised treatment plans for individual patients.

Pharmacogenomics examines how genetic variations influence drug responses, aiding in the personalisation of therapies and the prevention of adverse effects. This approach is particularly valuable in oncology, where it allows the selection of targeted treatments based on individual genetic profiles (Li et al., 2024).

By understanding genetic differences among individuals, healthcare providers can adjust drug dosages to maximise efficacy and minimise adverse reactions. For instance, genetic testing of the CYP2D6 enzyme helps determine optimal dosages for psychotropic medications, improving therapeutic outcomes while reducing side effects (Qayyum et al., 2023).

These examples highlight the positive impact of personalised medicine on patient care, offering treatments tailored to individual genetic profiles and contributing to more efficient and precise healthcare approaches.

The implementation of personalised medicine (PM) in healthcare systems presents numerous challenges, ranging from data integration to ethical and regulatory issues (Allen, 2024). One of the primary obstacles is the combination and analysis of diverse datasets, which include genetic information, environmental factors, and lifestyle data. The lack of common standards and interoperable digital platforms can lead to data fragmentation, highlighting the need for efficient technological integration solutions within medical systems (Ugajin, 2023).

Patient data privacy and security remain major concerns, particularly with the increasing use of artificial intelligence (AI). The risk of medical data misuse and potential algorithmic biases necessitate strict protection measures and auditing mechanisms to ensure fairness in medical decision-making. Furthermore, the use of "black-box" AI systems can generate distrust among healthcare professionals, making algorithm transparency and decision explainability essential (Allen, 2024).

Validating machine learning models for clinical applications presents additional challenges, as these technologies must comply with strict regulatory requirements and demonstrate both efficacy and safety before being deployed in medical practice. Additionally, ensuring that personalised medicine solutions are accessible to all patient groups, including marginalised populations, is necessary to prevent inequalities in healthcare.

Another significant barrier is the need for effective interdisciplinary collaboration among clinicians, medical informatics experts, and statisticians, ensuring that AI models are translated into clear and actionable insights for clinical practice. Moreover, data protection regulations are not yet sufficiently adapted to the rapid digitalisation of healthcare, creating difficulties in integrating new technologies into clinical workflows (Stenzinger et al., 2023).

The high costs of advanced technologies represent another factor that may slow down the adoption of personalised medicine. While healthcare digitalisation offers immense potential for data collection and

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analysis, it is essential to address financial challenges and data protection concerns to ensure sustainable implementation.

These challenges underscore the necessity of close collaboration between healthcare institutions, researchers, technology developers, and regulatory authorities to create an efficient and sustainable ecosystem. Such an approach would enhance patient care and bring wider societal benefits.

2.3. The impact of artificial intelligence on healthcare management

Artificial Intelligence (AI) plays an essential role in improving the operational efficiency of healthcare systems by automating processes and optimising resource allocation. Workflow automation reduces administrative tasks such as clinical documentation, appointment scheduling, and patient follow-ups, allowing healthcare professionals to dedicate more time to direct patient care (Hampel et al., 2023). Additionally, AI enhances hospital resource management, ensuring optimal allocation of staff, equipment, and facilities, thereby minimising waste and improving efficiency (Prabhod, 2024).

One of AI's most significant benefits in healthcare is its ability to reduce diagnostic time. Advanced algorithms, including convolutional and recurrent neural networks, analyse medical images and diagnostic data with high accuracy, minimising the risk of human error and ensuring more consistent interpretation of results (Delpierre & Lefèvre, 2023). AI can detect microscopic abnormalities in medical imaging, supporting radiologists in delivering faster and more precise diagnoses, thereby optimising radiology department workflows. Furthermore, AI algorithms can prioritise cases based on urgency, allowing medical staff to focus on critical patients (Shiwlani et al., 2024).

AI-powered remote monitoring systems, integrated with Internet of Things (IoT) devices, play a vital role in continuous patient supervision. These technologies analyse real-time physiological parameters and alert medical teams to significant changes, enabling proactive interventions. By reducing the need for frequent hospital visits, AI-driven monitoring systems help lower hospital admission rates (Prabhod, 2024).

The integration of AI into healthcare management has the potential to reduce costs significantly and optimise operational processes. AI processes large volumes of data, including genomic information, to tailor treatments to individual patient characteristics, thereby minimising trial-and-error approaches in therapeutic planning (Shiwlani et al., 2024).

Machine learning algorithms enhance predictability in treatment outcomes, facilitating personalised care while eliminating unnecessary tests and procedures. AI-driven solutions also optimise supply chain management, ensuring the availability of medical resources, preventing shortages, and reducing associated costs (Qayyum et al., 2023; Nwosu, 2024).

Beyond clinical workflow improvements, AI is also used to streamline healthcare administration, including resource management and patient scheduling, leading to substantial cost savings for healthcare organisations. This approach opens new opportunities for professionals across various disciplines to contribute to healthcare management improvements.

Leveraging big data and predictive analytics enables data-driven decision-making in patient care and medical resource allocation. AI models can forecast patient flow trends, ensuring optimal infrastructure use and dynamic adaptation to evolving healthcare demands (Ugajin, 2023).

Machine learning algorithms analyse vast datasets, including electronic health records (EHRs), clinical notes, and test results, generating critical insights for early disease detection and diagnosis. Predictive analytics powered by big data helps healthcare providers optimise treatment planning, allocate resources more efficiently, and improve patient outcomes (Prabhod, 2024).

The COVID-19 pandemic underscored the importance of digitalisation in healthcare and the adoption of AI-driven technologies to support medical service delivery. In response, the WHO/Europe Programme on Data and Digital Health assists countries in integrating digital solutions to enhance health system performance and strengthen public health functions (Cioantă-Păcuraru, 2024).

3. RESEARCH METHODOLOGY

The purpose of this study is to analyze the evolving trends in scientific research by examining key themes, keywords, and their relationships across various domains. By utilizing data visualization techniques, the study aims to identify dominant research areas, emerging topics, and the role of artificial intelligence and big data in modern scientific advancements.

A key focus is on understanding the integration of AI-driven methodologies in healthcare, particularly in diagnosis, classification, and personalized medicine. The study also explores the impact of computational techniques, such as deep learning and neural networks, in improving medical research and decision-making processes.

Through thematic mapping and keyword analysis, the study seeks to provide insights into how foundational research topics connect with specialized and emerging themes. The findings aim to guide researchers in identifying influential areas, recognizing potential research gaps, and understanding the trajectory of future scientific developments.

By correlating these findings with the existing scientific literature, the study aims to provide insights into the future of AI in personalised medicine, underlining the need for clear regulations and sustainable adoption strategies within healthcare systems.

This study adopts a qualitative research approach, primarily focusing on investigating the impact of AI on personalised medicine and healthcare management efficiency. The research relies on both secondary

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sources from scientific literature and case studies, which illustrate AI implementation in medical institutions and pharmaceutical companies worldwide.

The documentary analysis includes peer-reviewed scientific articles, reports from international healthcare organisations, and impact studies on AI adoption in medical systems. These sources provide a comprehensive understanding of current trends and the challenges faced in integrating new technologies into healthcare.

The selected case studies focus on hospitals, clinics, and companies that have successfully implemented AI in diagnostics, treatment, and medical workflow optimisation. Notable examples such as Mount Sinai Hospital, Mayo Clinic, and the NHS demonstrate the advantages of advanced algorithms in early disease detection and personalised treatments. By integrating these case studies, the research highlights effective implementation models, as well as the limitations and challenges encountered during AI adoption in clinical practice.

Data interpretation is conducted using a comparative approach, correlating the results obtained from the analysed institutions with findings reported in scientific literature. This method enables the identification of general success patterns and highlights the critical factors influencing the efficacy of AI in healthcare.

To ensure the relevance and validity of the conclusions, the research takes into account ethical considerations and international regulations governing AI applications in medicine. Key aspects examined include patient data protection, algorithm transparency, and the level of acceptance of advanced technologies among healthcare professionals.

This methodological approach provides a comprehensive perspective on how AI is transforming healthcare systems, emphasising both the benefits and the challenges associated with its implementation.

4. RESULTS

Artificial Intelligence (AI) is playing an increasingly significant role in transforming healthcare systems, contributing to optimised diagnostics, personalised treatments, and improved operational efficiency. Numerous hospitals, clinics, and companies worldwide have implemented AI-based solutions, achieving significant results in cost reduction and enhancing medical care quality.

Figure 1 illustrates the most relevant sources in terms of the number of published documents, providing insight into the key journals contributing to the analyzed research field. By displaying the distribution of publications across various sources, the visualization helps identify the most influential journals and their relative impact. The differences in the number of documents suggest varying levels of research activity, with some journals playing a more prominent role in disseminating knowledge within the domain.

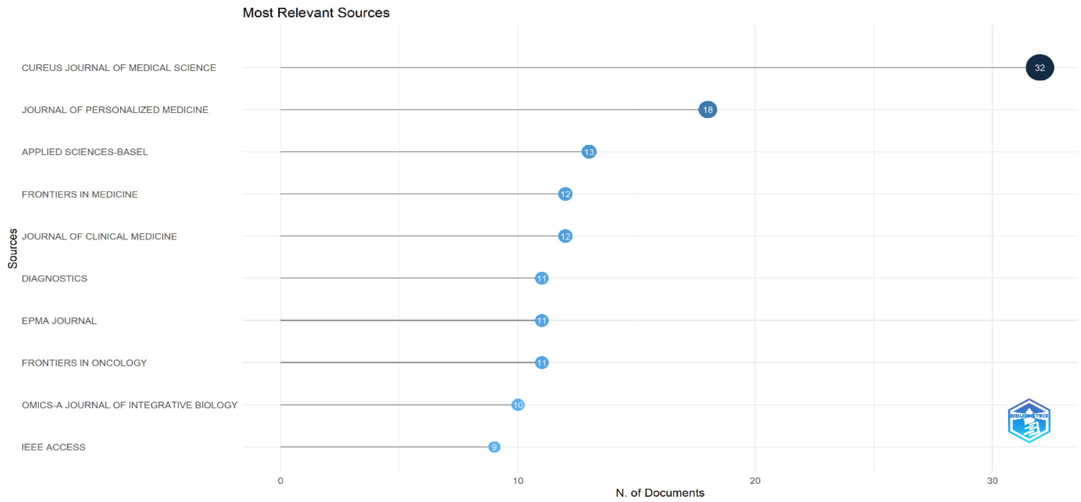

FIGURE 1. ANALYSIS OF THE MOST RELEVANT SOURCES BASED ON THE NUMBER OF PUBLICATIONS
Source: Own creation with Biblioshiny

Figure 1 presents the most relevant sources based on the number of published documents. The most prolific source is Cureus Journal of Medical Science, with a total of 32 documents. The next most significant source is the Journal of Personalized Medicine, with 18 documents, followed by Applied Sciences-Basel, which has published 13 papers. Frontiers in Medicine and Journal of Clinical Medicine each have 12 documents, while Diagnostics, EPMA Journal, and Frontiers in Oncology have contributed 11 articles each. OMICS-A Journal of Integrative Biology has published 10 papers, and IEEE Access concludes the list with 8 documents.

The visualization highlights the importance of these sources in the research field and illustrates the distribution of documents across different publications. A notable difference can be observed between the first source and the rest, indicating the greater influence of the Cureus Journal of Medical Science in the analyzed domain.

Figure 2 visualizes the publication trends of various authors over a period of years, highlighting their research activity and impact. The size of the circles represents the volume or significance of contributions in specific years, providing insights into patterns of academic productivity. By examining these trends, it becomes possible to identify prolific researchers, peak publication periods, and potential collaborations or research focus shifts.

Figure 2 shows that publication activity is distributed across multiple years, with certain authors demonstrating peaks in their research output at different times. Some authors, such as Ahmed Z and Basit AW, have distinctively larger markers in specific years, suggesting a significant contribution in those periods. Other authors, like Wang Y and Zhang L, show consistent publication activity over the years, indicating sustained research involvement.

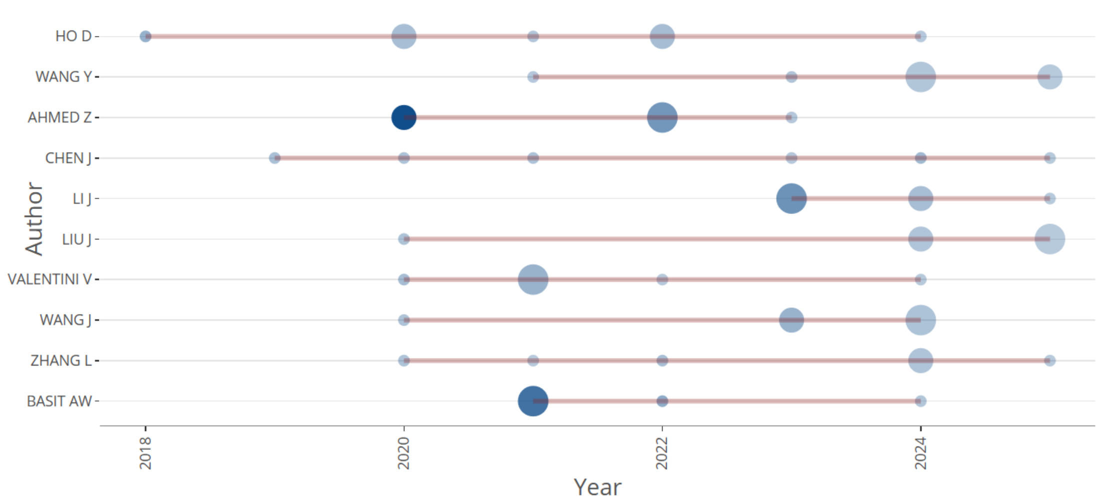

FIGURE 2. PUBLICATION TRENDS OF AUTHORS OVER TIME
Source: Own creation with Biblioshiny

Several authors, including Chen J, Liu J, and Valentini V, exhibit multiple smaller markers spread over time, suggesting steady contributions rather than single impactful publications. The distribution of research outputs suggests that some authors have periodic peaks, while others maintain a steady presence in their field. The Figure also indicates an increasing trend in research activity approaching 2024, suggesting growing contributions from multiple authors.

Table 1 presents data on the research activity of different authors over various years, showing the number of publications (freq), total citations (TC), and total citations per year (TCpY). By analyzing these metrics, we can assess the impact of each author's contributions and identify trends in their academic influence. The data helps in understanding which years were most significant for specific authors in terms of research visibility and citation impact.

TABLE 1. AUTHORS' RESEARCH IMPACT OVER TIME

Author	year	freq	TC	TCpY
AHMED Z	2020	2	299	49.833
AHMED Z	2022	3	82	20.500
AHMED Z	2023	1	3	1.000
BASIT AW	2021	3	177	35.400
BASIT AW	2022	1	48	12.000
BASIT AW	2024	1	3	1.500
CHEN J	2019	1	28	4.000
CHEN J	2020	1	17	2.833
CHEN J	2021	1	15	3.000
CHEN J	2023	1	3	1.000

Source: Own creation with Biblioshiny

In Table 1, Ahmed Z had a peak in 2020 with two publications accumulating 299 citations, making it the most impactful year for this author. Despite publishing more frequently in 2022, the total citations were lower, indicating a reduced impact compared to 2020. By 2023, the impact further declined, with only one publication receiving minimal citations.

Basit AW showed notable research activity in 2021 with three publications earning 177 citations, reflecting a strong influence that year. In the following years, the citation count decreased, with 48 citations in 2022 and a further drop in 2024. This suggests that the author's most significant contributions were in 2021, with a declining impact afterward.

Chen J had steady but lower citation counts compared to the other authors. The most cited year was 2019, with 28 citations from a single publication. The following years showed consistent but lower citation rates, suggesting sustained research activity but with a more moderate impact. The drop in total citations in 2023 indicates a reduced influence in recent years.

Overall, the data highlights that while some authors have had highly impactful years, their citation influence varies over time. Certain years stand out as peaks for specific authors, whereas others exhibit more stable but lower-impact contributions.

In Figure 3, this tree map visualization presents the distribution of key research topics based on their frequency of occurrence. Each block represents a specific keyword, with the size of the block indicating its prominence in the dataset. The percentages reflect the proportion of each keyword within the overall research landscape. This visualization helps identify dominant themes and emerging trends in the field.

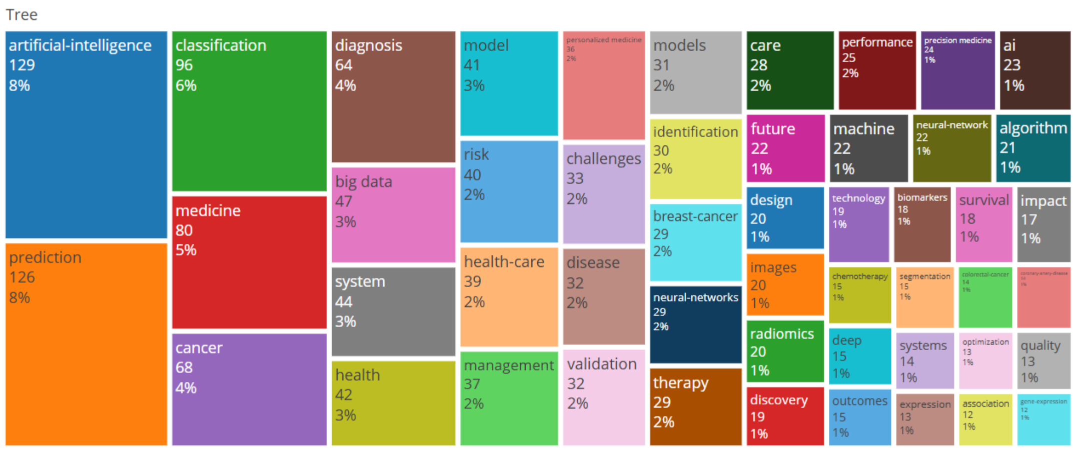

FIGURE 3. KEYWORD DISTRIBUTION IN RESEARCH TOPICS
Source: Own creation with Biblioshiny

In Figure 3, the most frequently occurring keywords are artificial intelligence (129 mentions) and prediction (126 mentions), each representing 8% of the dataset. This highlights the significant role of AI-driven predictive models in research. Classification (96 mentions) and medicine (80 mentions) also stand out as major themes, indicating a strong focus on categorization techniques and medical applications.

Other notable keywords include cancer (68 mentions), diagnosis (64 mentions), and big data (40 mentions), reflecting an emphasis on healthcare-related research and the integration of large-scale data analytics. Topics such as health-care, risk, and disease indicate broader applications in medical decision-making and patient management.

Emerging themes like neural networks, machine learning, and deep learning suggest the growing impact of advanced computational methods in research. Additionally, keywords related to performance, validation, and quality point to a focus on ensuring the reliability and effectiveness of proposed models.

Overall, the visualization highlights the dominance of AI, machine learning, and predictive analytics in research, particularly within medical and healthcare applications. It also suggests ongoing efforts to improve classification accuracy, diagnostic processes, and system validation in various domains.

Figure 4 presents the most frequently occurring keywords in research publications, highlighting the dominant themes in the analyzed dataset. The number of occurrences for each keyword reflects its relevance and impact in the field. By examining these keywords, we can identify major research trends and the focus areas of recent studies.

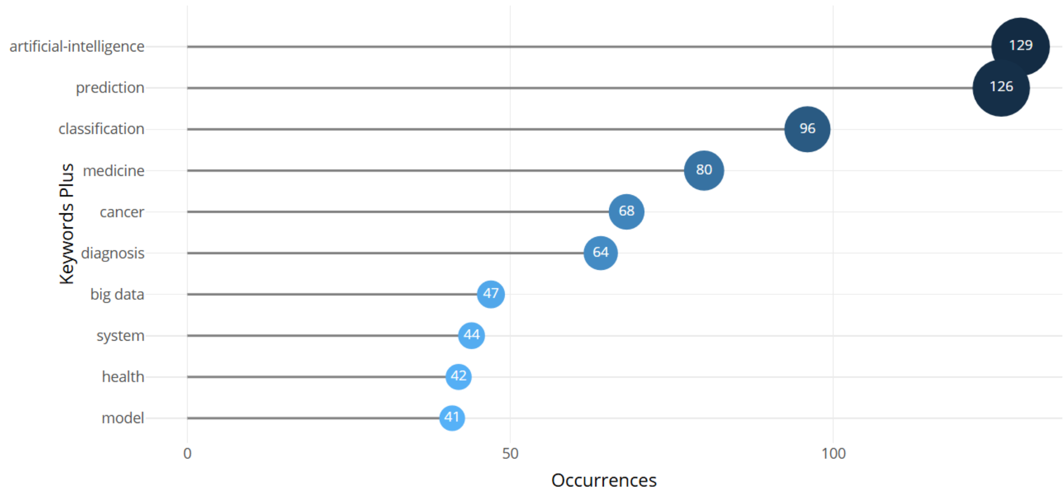

FIGURE 4. TOP KEYWORDS IN RESEARCH PUBLICATIONS
Source: Own creation with Biblioshiny

In Figure 4, the most prominent keyword is artificial intelligence, appearing 129 times, followed closely by prediction with 126 occurrences. This indicates a strong emphasis on AI-driven predictive models in research. Classification (96 occurrences) and medicine (80 occurrences) are also widely referenced, suggesting that AI applications in medical research and classification techniques are key areas of study.

Other significant keywords include cancer (68 occurrences) and diagnosis (64 occurrences), reflecting a focus on healthcare and disease detection. Big data (47 occurrences) highlights the importance of large-scale data analysis in research. Additionally, terms like system (44 occurrences), health (42 occurrences), and model (41 occurrences) indicate an interest in developing structured methodologies and frameworks for various applications.

Overall, the visualization demonstrates that artificial intelligence, predictive analytics, and healthcare-related topics are central to current research trends. The prevalence of these keywords suggests that advancements in AI and data-driven models are playing a fundamental role in shaping modern research.

In Figure 5, this word cloud visualization represents the most frequently used keywords in research publications, with the size of each word indicating its relative frequency. Larger words appear more often, highlighting the dominant themes and areas of focus in the analyzed dataset. This visualization provides an intuitive way to understand key research trends and emerging topics.

FIGURE 5. KEYWORD FREQUENCY IN RESEARCH PUBLICATIONS
Source: Own creation with Biblioshiny

In Figure 5, the most prominent keywords are artificial intelligence, prediction, and classification, indicating a strong emphasis on AI-driven methodologies and predictive models in research. Medicine and diagnosis also appear prominently, suggesting a major focus on healthcare applications. Cancer, big data, and health-care are frequently mentioned, emphasizing the role of data-driven technologies in medical research.

Other significant terms include neural networks, risk, system, model, and validation, which reflect the technical aspects of AI and machine learning applications. Keywords like personalized medicine, management, and therapy suggest an interest in tailored healthcare solutions and treatment optimization.

Overall, the word cloud highlights the central role of artificial intelligence and predictive analytics in modern research, particularly within medicine and healthcare. It also suggests a growing intersection between machine learning, big data, and medical advancements.

In Figure 6, this thematic map categorizes research topics based on their level of development and relevance. The vertical axis represents the degree of development, while the horizontal axis reflects relevance within the research field. The four quadrants provide insight into different types of themes,

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ranging from highly relevant and well-developed topics to emerging or less central ones. This visualization helps in understanding key research areas and their impact.

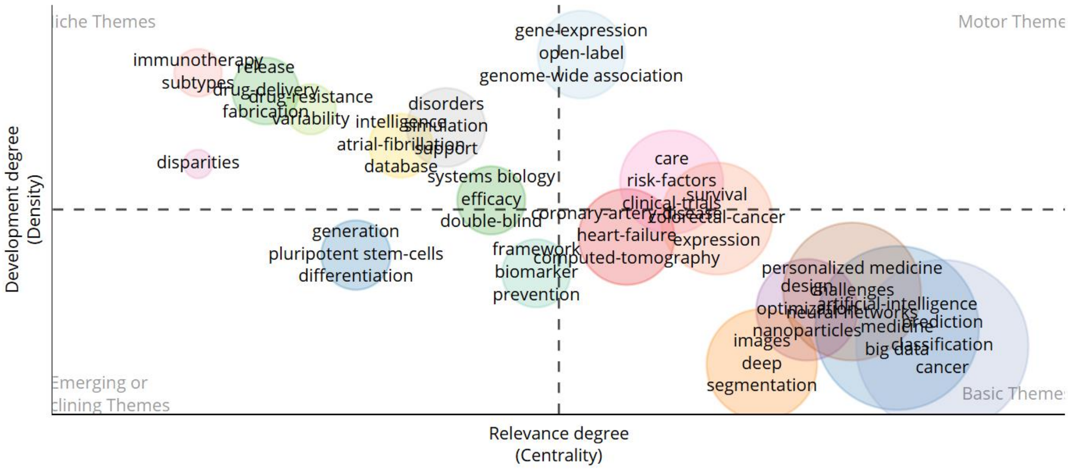

FIGURE 6. THEMATIC MAP OF RESEARCH TOPICS
Source: Own creation with Biblioshiny

In Figure 6, motor themes, located in the top-right quadrant, include gene expression and genome-wide association, which are both highly developed and essential to research advancements. These topics are well-established and play a significant role in shaping the field.

Basic themes, found in the bottom-right quadrant, consist of artificial intelligence, prediction, personalized medicine, classification, big data, and cancer. These are widely studied and form the foundation of ongoing research efforts. Their centrality suggests they are essential for various applications and have broad scientific relevance.

Niche themes, positioned in the top-left quadrant, include immunotherapy, fraud detection, atrial fibrillation, and variability intelligence. These topics are specialized, indicating focused research with a deep but more limited scope. While well-developed, they are not as widely connected to other research areas.

Emerging or declining themes, appearing in the bottom-left quadrant, include pluripotent stem cells, generation, and differentiation. These topics show lower development and relevance, suggesting they may either be gaining interest as emerging research directions or losing significance over time.

The thematic map highlights artificial intelligence and predictive analytics as fundamental research areas, while clinical applications such as precision medicine and risk factors remain key drivers of scientific progress. The presence of niche and emerging themes indicates ongoing advancements and the potential for future breakthroughs in specialized fields.

In Figure 7, this scatter plot visualizes the relationships between key research topics based on their distribution along two dimensions. The positioning of keywords reflects their associations, with closer terms indicating stronger connections in the research landscape. The spread of topics provides insights into different thematic clusters and their relative significance within the field.

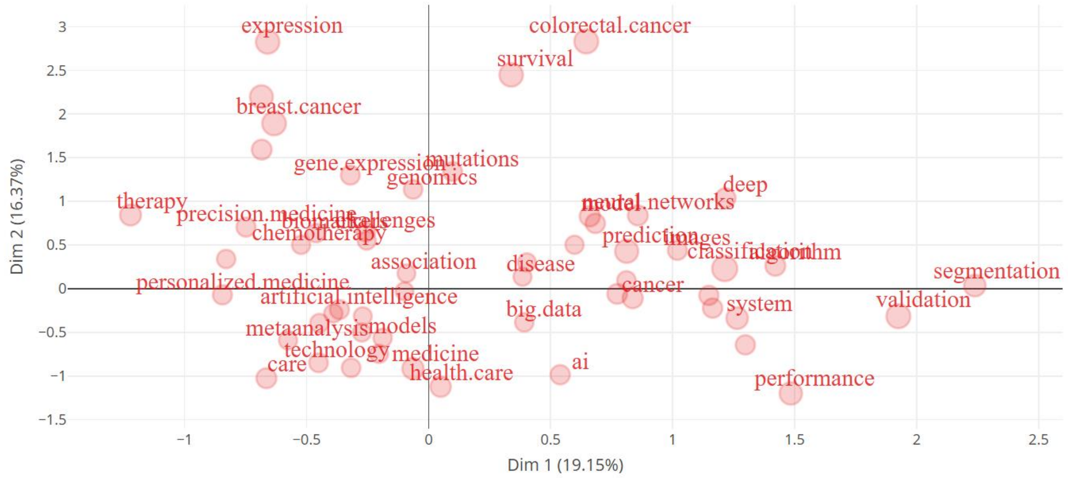

FIGURE 7. KEYWORD MAPPING IN RESEARCH TOPICS
Source: Own creation with Biblioshiny

In Figure 7, keywords like artificial intelligence, big data, medicine, and health-care are positioned near the center, indicating their broad relevance across multiple research areas. Their central placement suggests they serve as foundational topics that connect various specialized fields.

In the upper-left region, terms such as breast cancer, gene expression, and genomics indicate a focus on molecular and genetic research. Their grouping suggests an emphasis on understanding disease mechanisms and genetic influences. Similarly, colorectal cancer and survival are positioned together, highlighting a focus on oncology and patient outcomes.

On the right side, topics like segmentation, validation, system, and algorithm suggest a computational and methodological research focus. These keywords relate to machine learning, model performance, and the development of advanced analytical techniques. The presence of deep learning and neural networks in this area reinforces the significance of AI-driven approaches in modern research.

The lower-left region contains terms like personalized medicine, precision medicine, chemotherapy, and therapy, reflecting a strong connection to clinical applications and treatment strategies. These keywords indicate a research emphasis on tailoring medical treatments to individual patients.

Overall, the visualization highlights the interplay between artificial intelligence, medical research, and computational methodologies. The clustering of related topics provides insights into the key areas of study, showing how AI-driven approaches are increasingly integrated into healthcare and disease analysis.

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5. DISCUSSION

A notable example is Mount Sinai Hospital in the United States, where machine learning algorithms are used to detect early-stage cardiac and pulmonary diseases. By analysing large clinical and imaging datasets, AI can identify subtle patterns that might be overlooked by human analysis (Mount Sinai, 2021). This assists doctors in decision-making, enabling early diagnosis and more effective treatments, which in turn has led to a significant reduction in complication rates and costs associated with late-stage treatments.

Another example is Mayo Clinic, which has adopted AI solutions for personalised cancer treatment. Using advanced algorithms, doctors can analyse patients' genetic profiles and recommend tailored therapies for each case (Mayo Clinic, 2024). This approach has improved cancer prognosis and reduced ineffective treatments and severe side effects.

In the UK, the National Health Service (NHS) partnered with DeepMind to develop a predictive system for acute kidney failure. By using neural networks to analyse patient medical data, the system can alert doctors up to 48 hours before a condition becomes critical (DeepMind, 2019). This enables faster and more efficient interventions, reducing both ICU admissions and the costs associated with treating advanced-stage diseases.

In Japan, Nagoya University Hospital implemented an AI-powered endoscopic analysis system for gastric cancer detection. Image processing algorithms detect precancerous lesions with higher accuracy than traditional methods, allowing for earlier and less invasive interventions (Hospital., 2024). Following its implementation, early diagnosis rates increased significantly, giving patients access to less aggressive treatments and reducing overall healthcare costs.

Pharmaceutical companies have also integrated AI into research and development processes, accelerating drug discovery. Insilico Medicine, a biotechnology company, uses AI to identify potential therapeutic molecules (Insilico Medicine). Their algorithms analyse millions of chemical structures and predict their efficacy against various diseases, significantly reducing the time needed to develop new drugs. This technology has enabled the discovery of potential treatments for diseases such as pulmonary fibrosis, saving resources and accelerating clinical trials.

In virtual healthcare, companies like Babylon Health have developed AI-based medical consultation systems that provide preliminary assessments and personalised recommendations. Using natural language processing (NLP) algorithms and extensive symptom databases, these systems guide patients toward appropriate treatments and help reduce pressure on emergency medical services (Babylon Health). Large-scale adoption of such solutions has led to fewer unnecessary consultations and optimised healthcare resource management.

Another significant example is Stanford Health Care, where AI is used to optimise physician workflows and consultation time management. By analysing patient appointment schedules and medical histories in real time, intelligent systems can prioritise complex cases and reduce patient waiting times (International Hospital Federation, 2024). This has resulted in higher patient satisfaction and more efficient use of medical resources.

In Romania, pilot projects led by MedLife and Regina Maria are exploring the use of AI in medical imaging analysis and patient data management optimisation. Although AI implementation in the Romanian healthcare system is still in its early stages, initial results indicate a reduction in diagnostic time and improved accuracy in medical interpretations (MedLife; Regina Maria).

To highlight the impact of AI in healthcare, multiple hospitals, clinics, and pharmaceutical companies have implemented innovative AI-driven solutions, leveraging advanced data processing algorithms, machine learning, and neural networks. These technologies have enhanced diagnostics, enabled personalised treatments, and improved medical resource management.

Table 2 presents some of the most notable examples of artificial intelligence (AI) integration in healthcare, highlighting specific applications and the achieved outcomes in cost reduction and improved medical service quality.

TABLE 2. AI IMPLEMENTATION IN HEALTHCARE SYSTEMS

Institution / Company	Country	AI Application	Key Outcomes
Mount Sinai Hospital	USA	Machine learning algorithms for cardiac and pulmonary disease detection.	Early diagnosis, reduced complications, and lower late-stage treatment costs (Mount Sinai).
Mayo Clinic	USA	AI algorithms for personalised oncology treatments.	Improved therapy effectiveness, reduced side effects, and fewer ineffective treatments (Mayo Clinic).
NHS & DeepMind	UK	Neural networks for acute kidney failure prediction.	Early alerts for doctors, reduced hospitalisations, and lower intensive care costs (DeepMind).
Nagoya University Hospital	Japan	Image processing for early gastric cancer detection.	Fast and accurate diagnosis, minimally invasive interventions, and reduced healthcare costs (Nagoya University Hospital).
Insilico Medicine	Global	AI algorithms for drug discovery.	Shortened research time and costs, faster identification of effective molecules (Insilico Medicine).
Babylon Health	UK	AI-based medical consultation systems.	Fewer unnecessary consultations, optimised healthcare resource allocation (Babylon Health).
Stanford Health Care	USA	Optimised scheduling and time management for doctors.	Reduced waiting times, improved patient satisfaction, and more efficient resource utilisation (International Hospital Federation).
MedLife & Regina Maria	Romania	AI-powered medical imaging analysis and patient data management.	Faster diagnostics, increased accuracy in medical interpretations (MedLife; Regina Maria).

Source: Own creation.

The adoption of artificial intelligence in medical systems has demonstrated that it not only enhances the quality of care but also contributes to the financial sustainability of hospitals and clinics. By reducing

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diagnostic errors, optimising resources, and personalising treatments, AI is redefining healthcare service management, offering a more efficient and accessible model for patients.

As technology continues to evolve, an increasing number of hospitals and healthcare companies are expected to adopt AI-based solutions. Investments in these technologies will enable not only better management of medical resources but also the development of more efficient healthcare systems, capable of responding to patients' needs quickly and effectively.

Although artificial intelligence (AI) brings numerous benefits to the medical field, its large-scale implementation comes with a range of challenges and limitations. These include ethical and legal concerns as well as difficulties related to the adoption of new technologies within healthcare systems. Some of the most significant obstacles include medical data confidentiality, resistance from healthcare professionals towards AI-based technologies, and the lack of clear regulations establishing usage standards and accountability.

One of the greatest challenges in implementing AI in medicine is ensuring the protection of patient data. AI systems require vast amounts of data for training and optimisation, and this data includes highly sensitive information such as medical history, diagnoses, and treatment records. While such data is essential for developing more accurate and efficient algorithms, its use raises concerns regarding privacy, security, and patient rights.

Medical data breaches can have serious consequences, ranging from the unauthorised use of information for commercial purposes to discrimination in access to healthcare services or insurance policies. For instance, if an insurance company gains access to a patient’s health data and identifies a predisposition to a particular illness, there is a risk of increased insurance premiums or even denial of coverage.

Another key ethical concern is patients' right to control their own data. Regulations such as the General Data Protection Regulation (GDPR) in the European Union impose strict rules on the use and storage of personal data. However, applying these regulations in the context of AI remains a challenge. A specific issue is that AI algorithms rely on aggregated data from multiple sources, making it difficult to identify and delete an individual patient’s information if they choose to exercise their "right to be forgotten."

The adoption of artificial intelligence in the medical field faces considerable resistance from healthcare professionals. Many doctors and medical staff remain sceptical about the accuracy of AI algorithms and fear that AI could replace human expertise. This reluctance is further fuelled by the lack of transparency in some AI systems, which operate as "black boxes" and do not provide clear explanations for their decisions. In a field where every medical decision can have life-or-death consequences, many clinicians prefer traditional diagnostic and treatment methods over automated solutions.

Beyond trust in technology, there are also practical challenges in implementing AI in hospitals and clinics. Integrating new technologies into existing systems requires significant investment in infrastructure, staff training, and updating work protocols. In many hospitals, IT systems are outdated and incompatible with advanced AI-based solutions, making the implementation of these technologies more difficult.

Another obstacle is patients' perception of AI in medicine. Many patients are hesitant to accept a diagnosis or treatment plan generated by an algorithm, preferring direct interaction with a doctor. Although studies indicate that AI can achieve equal or even superior accuracy in certain fields, such as radiology or dermatology, widespread patient acceptance of this reality requires time and education.

Another major challenge is the lack of clear regulations regarding the use of artificial intelligence in medicine. Unlike other industries, such as the automotive or financial sectors, where AI usage is already subject to detailed regulations, the healthcare sector is still in the early stages of establishing appropriate legislative frameworks.

One of the key legal issues concerns liability in cases where an AI algorithm produces an incorrect diagnosis or recommends an inappropriate treatment. In such situations, it is difficult to determine who bears legal responsibility—the algorithm's developers, the medical institution, or the doctor who used AI in the decision-making process.

Current regulations, such as the Medical Device Regulation (MDR) in the European Union and the standards set by the Food and Drug Administration (FDA) in the United States, impose strict requirements for validating AI algorithms in medicine. However, these regulations are still in the process of adaptation and do not cover all possible scenarios. For instance, AI is a dynamic field in which algorithms continuously improve through machine learning, raising questions about the need for periodic recertification.

To ensure the safe and effective implementation of AI in healthcare, close collaboration between regulatory authorities, the medical community, and technology developers is essential. Standardising processes, ensuring algorithm transparency, and developing clear protocols for AI-assisted medical decision-making are indispensable steps in building trust in these technologies and safeguarding patient rights.

The implementation of artificial intelligence in healthcare has yielded significant results, as confirmed and supported by the scientific literature. Recent studies highlight the benefits of using advanced algorithms in diagnostics, treatment, and medical management optimisation, demonstrating cost reduction, increased diagnostic accuracy, and improved patient outcomes (Khalifa & Albadawy, 2024).

A study on neural networks used in ophthalmology has shown that AI can surpass specialist doctors in detecting diabetic retinopathy (Wang et al., 2022).

AI-assisted genomic analysis enables faster identification of tumour markers, leading to more effective therapies (Das et al., 2024). The literature indicates that AI-based predictive models in oncology have significantly improved patient selection for immunotherapy (Yin et al., 2022).

Regarding the use of AI in predicting kidney failure, the collaboration between the NHS and DeepMind has demonstrated the efficiency of deep learning algorithms. A study found that AI predictive models can anticipate acute kidney failure up to 48 hours before onset, enabling early interventions and reducing mortality rates (Koyner et al., 2018). These findings align with data obtained from the NHS, where AI implementation has reduced emergency admissions and improved the allocation of medical resources.

Another study indicates that image-processing algorithms can detect malignant lesions with accuracy, outperforming conventional methods (Saba, 2020).

AI-based medical consultation applications, such as those used by Babylon Health, are supported by research published by Gellert (2023), which indicates that virtual medical assistants can reduce the burden on healthcare systems by effectively triaging patients. A study by Li et al. (2024) found that these systems can reduce unnecessary doctor visits.

In Romania, the adoption of AI solutions by MedLife and Regina Maria for image analysis and patient data management is a recent trend, but one that aligns with international literature. Research by Bhandari (2024) shows that AI applied in radiology can reduce the time required for interpreting medical images, explaining the promising results observed in Romanian hospitals (Bhandari, 2024).

Thus, the scientific literature fully supports the benefits of AI implementation in healthcare, confirming the results obtained in the analysed medical institutions. Whether in early diagnosis, personalised treatments, patient flow optimisation, or the discovery of new therapies, empirical data shows that AI enhances efficiency and sustainability in healthcare systems worldwide.

Although artificial intelligence has the potential to revolutionise medicine, its implementation poses numerous challenges, from data protection and resistance to change to the lack of clear regulations. Overcoming these obstacles requires a multidisciplinary approach, integrating technological advancements with legislative adaptations and mindset shifts among healthcare professionals. As AI becomes increasingly integrated into medical systems, it is paramount to ensure a balance between innovation, ethics, and patient safety.

6. CONCLUSIONS

The analysis of research trends and keyword distributions across various visualizations highlights several key insights into the evolving landscape of scientific studies.

Artificial intelligence and predictive analytics emerge as dominant themes, consistently appearing as central topics across multiple visualizations. Their integration into healthcare, particularly in areas such as diagnosis, classification, and personalized medicine, underscores the increasing reliance on AI-driven methodologies for improving medical research and patient care.

Healthcare-related research remains a core focus, with frequent mentions of cancer, disease, health-care, and precision medicine. The clustering of oncology-related terms, such as breast cancer, colorectal cancer, and survival, indicates that AI and big data applications are playing a integral role in early detection, treatment, and patient outcome prediction.

Computational techniques, including deep learning, neural networks, segmentation, and validation, are prominent across multiple analyses. These keywords highlight the methodological advancements being integrated into medical and scientific research, reinforcing the importance of data-driven decision-making and model optimization.

Thematic mapping and keyword positioning suggest a structured research landscape where well-established topics, such as artificial intelligence and big data, serve as foundational areas, while emerging and niche themes, including pluripotent stem cells and variability intelligence, indicate potential future directions.

Overall, the findings demonstrate a strong intersection between artificial intelligence, medical research, and computational advancements. AI-driven approaches are reshaping healthcare and diagnostics, while precision medicine and personalized treatment strategies are gaining traction. The integration of big data and machine learning continues to drive innovation, with ongoing developments likely to refine and expand the applications of these technologies in scientific research.

Artificial intelligence has had a significant impact on personalised medicine, transforming diagnosis, treatments, and patient management. With its ability to rapidly analyse vast amounts of data and identify complex patterns, AI has enhanced diagnostic accuracy, reduced medical errors, and enabled the personalisation of therapies based on each patient's genetic profile and medical history. These advancements not only improve the efficiency of medical care but also contribute to optimising healthcare resources, lowering costs, and increasing access to medical services.

Among the main benefits of AI in personalised medicine are faster and more accurate diagnoses, optimised treatments through advanced machine learning algorithms, and a reduction in the time required for drug discovery. AI also allows for more efficient patient monitoring through telemedicine technologies and connected health devices, facilitating early interventions and the prevention of severe conditions. These innovations lead to a more proactive healthcare system focused on prevention and personalisation rather than the traditional model of treating diseases in advanced stages.

However, integrating AI into medicine presents challenges related to algorithm transparency, legal regulations, and patient data protection. The future of AI in healthcare depends on three key areas of development.

One of the main obstacles to the widespread adoption of AI in medicine is the lack of algorithm transparency, often referred to as the "black box problem". Doctors and patients need to understand the reasoning behind AI-generated recommendations to trust automated decisions. Future research will focus on developing Explainable AI (XAI) models that provide clear justifications for each diagnosis or treatment plan. This aspect is critical for increasing AI adoption in medical practice and ensuring effective collaboration between technology and healthcare professionals.

As AI plays an increasingly important role in clinical decisions, clear regulations are needed for its use in healthcare. Legislation must establish precise standards for validating medical algorithms, define legal responsibility in case of errors, and impose strict requirements for patient data protection. International organisations such as the US Food and Drug Administration (FDA) and the European Medicines Agency are already working on stricter certification standards for AI-based solutions, but this process must be accelerated to keep pace with rapid technological innovation.

Another promising future direction is the use of blockchain technology for managing and securing medical data. Blockchain provides a decentralised and transparent system for storing information, allowing patients to retain control over their own data and decide who can access it. This technology could address some of the privacy and security concerns associated with AI, ensuring the traceability and integrity of medical records. Additionally, blockchain integration could facilitate information sharing between hospitals, clinics, and researchers, accelerating innovation in personalised medicine.

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