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Mapping Precision Medicine Research: A Scientometric and Network Visualization Approach

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Abstract — In the realm of Precision medicine, it has been increasingly recognized that individuals affected by the same disease have intricate biological profiles. Precision medicine strives to enhance the health of patients by acquiring the most effective medicines based on individual variations in genes, including somatic and inherited. The field has endured rapid advancements prompted by technologies such as Big Data, Digital Twins, Artificial Intelligence, Deep Learning, and Data Analytics. This study employs quantitative approach to execute Sciento- metric Analysis of the articles indexed in the Web of Science Database. A searching string was generated through the selection of pertinent keywords, and certain parameters such as publishing year, research subject and financing organization were examined. The bibliometric networks were examined and visualized by employing software named VOSViewer. A total of 1352 papers were obtained between 2013 and 2022, with a notable surge in research output in 2019 and increased to 203-219 publications annually over the preceding three years. The most substantial disciplines in healthcare are genetics and healthcare science, which contributes to an upsurge in publications and citations. Genetic testing and genomic medicine are among the foremost recent trends in Precision medicine research. This paper provides the implementation, most recent trends, and worldwide study geography over the preceding ten years which aid in determining preliminary research and providing recommendations for further studies.

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Index Terms — Precision medicine, personalized healthcare, Digital twin, Deep learning, Artificial Intelligence.

I. Introduction

The healthcare sector has been evolving towards smart health and intelligent healthcare systems in recent decades. The healthcare sector is constantly growing with new scientific breakthroughs, treatment and technologies such as Artificial Intelligence and Data Science [1], [2]. Smart healthcare, adapted from the notion of ”smart planet” addressed by IBM in 2009, which involves smart technologies that employ IoT devices to sense and transmit information through supercom- puters and cloud computing [3], [4]. In all aspects of smart healthcare, Industry 5.0 enabling technologies such as Digital Twin, Virtual Reality, 6G and above, etc, have been extensively deployed [5], [6]. From the patients’ perspective, individuals can use wearable devices to track their health and receive medical help through virtual assistants. These innovations in smart healthcare can reduce the risk of medical treatments and enhance the efficacy of the utilization of medical assets. In smart healthcare, Precision Medicine is a growing area that aims to provide personalized healthcare based on the unique genetic data, environmental, and lifestyle aspects of patients [7].

This approach focuses on disease treatment by integrating an individual’s multi-genomic data to make a patient’s per- sonalized decision [8]. Precision medicine facilitates break- throughs in healthcare, including medical decisions, medical treatments, and medical devices customized to a patient based on the knowledge of their genes, environment, and lifestyle. The major objective of precision medicine is the provision of rational pharmacotherapy, which essentially prescribes the appropriate medication to the appropriate patient in the proper dosage at a suitable moment without causing harm to the patient [9]. Precision medicine innovations have culminated in beneficial advantages such as early identification of dis- eases and the formation of personalized treatments, which are growing increasingly frequent in healthcare.

Precision medicine’s proficiency to personalize treatment is facilitated by an assortment of gathering and analysis tools. In addition, precision medicine is another concept that integrates different aspects: big data, used to analyze large amounts of health information; genomics, which deals with the study of genes and the functions they play in health and illness; and pharma- cogenomics, which explores how genetic variation influences how individuals respond to medications [10], [11]. Moreover, patient satisfaction is a critical consideration that will ensure the treatment plan is aligned with the preferences and needs of the patients. Figure 1 illustrates how all these components relate to each other, showing their importance to the overall precision medicine framework.

A. Precision Medicine: A Key Component of Smart Healthcare

One of the most promising areas within smart healthcare is Precision Medicine. This approach utilizes a patient’s genetic, environmental, and lifestyle data to deliver highly customized healthcare

[12]. Precision medicine enables medical treat- ments, decisions, and devices to be tailored to a particular individual's specific biological information in contrast to tra- ditional "one-size-fits-all" treatment techniques [13]. Essen- tially, precision medicine brings rational pharmacotherapy: the appropriate drug given to the appropriate patient at the appropriate time through the right route in a dosage that minimizes toxicity but maximizes therapeutic effect [14].

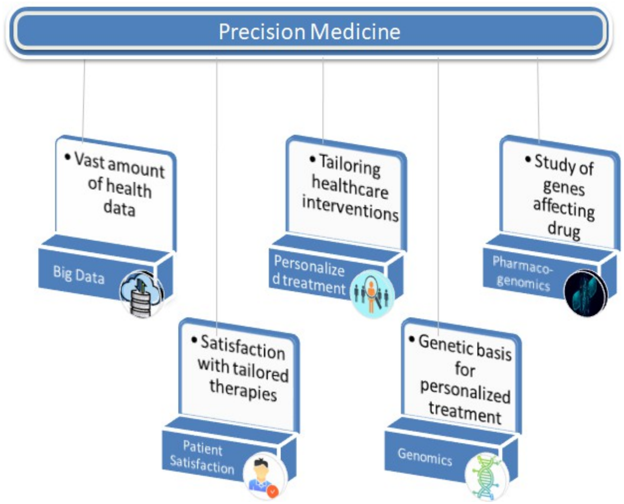

Fig. 1. Essential aspects of Precision Medicine.

B. *The Impact of Precision Medicine in Cancer Care*

Precision medicine has revolutionized the approach to can- cer, as it has now become possible to detect such diseases at earlier stage, along with developing targeted therapies. Cancer is heterogeneous and complex-there is not only variability between cancer types but also diversity within subtypes and individual tumors. Cancer treatments have been traditionally based on the location and stage of the tumor and, therefore, approached on a generalized basis, such as surgery, chemother- apy, and radiation therapy. These therapies usually do not account for the genetic variation in tumors, and therefore, the end products of such treatments often turn out to be worthless and seriously side-effect-rich. In contrast, precision medicine strategies rely more on the molecular and genetic profiles of each patient's cancer. In this regard, next-generation genomic sequencing can identify specific mutations and alterations supporting tumor growth [2], [7] . Targeted therapies-tyrosine kinase inhibitors (TKIs) for EGFR mutations in NSCLC or HER2 inhibitors in breast cancer-have revolutionized clinical outcomes [15], [16].

C. *Contribution of Genomics, AI, and Big Data to Precision Medicine in Cancer Detection*

Genomic profiling has now emerged as an essential tool in precision oncology [17]. Cancer tissues can be correlated with healthy cells for comparison. By tracing these cancer- causing genes or mutations within those tissues, this infor- mation is employed as a guide by the clinicians in choosing the appropriate cancer therapy so that they can use therapies directed to specific molecular alterations

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of the cancer cells. Even more targeted are the therapies that rely on the presence of biomarkers, such as BRCA1 and BRCA2 mutations in breast and ovarian cancer, determining the outcome of PARP inhibitors [18], [19]. The integration of artificial intelligence and big data analytics at the top of advancing precision medicine, more specifically, cancer detection, can help unravel by analyzing vast datasets that include genomic information, medical records, imaging studies, and clinical trials. AI algo- rithms can thus identify patterns in these vast datasets that may aid in early detection and personalized treatment. For instance, machine learning models can perhaps scan mammography or MRIs for the look of early cancers with much more precision than would be achieved using normal scientific methods. The modeling approach of a treatment response can also be utilized, whereby an AI could predict treatment responses to patients who enroll in certain clinical studies, and this will be applied to some other subjects with a similar genetic profile.

D. *Innovations in Non-Invasive Cancer Detection: Liquid Biopsy*

The emergence of liquid biopsy is yet another breakthrough in the field of diagnosis of cancer. Traditional tissue biopsies, although they are useful, can be surgical and pose dangers to the patients. It has been found that liquid biopsy, which looks at circulating tumor DNA (ctDNA) in the blood, is a good substitute [20]. These biopsies help in the continuous observation of the disease and the investigation as to how effective the treatment is. For instance, if the cancer patient is tested even if the tumor is not yet seen and cancer mutations are detected, then the treatment can take place at a much earlier stage, thus allowing for better healing [6], [9] .

E. *The Future of Precision Medicine: Multi-Omics and Im- munotherapy*

A better understanding of the biological processes under- lying cancer and even advanced ways of treatment can be achieved only by integrating diverse approaches, including proteomics, metabolomics, transcriptomics, and genomic ap- proaches. Furthermore, opportunities will emerge to develop new therapeutic approaches. The emergence of immunother- apy approaches tailored for a patient’s immunophenotype provides new avenues for targeted therapy [10]. The growing use of EHRs and the expanding popularity of digital health platforms enhance the effectiveness of data capture and shar- ing, resulting in the availability of more tailored treatment options [7], [8], [21].

II. RELATED WORK

In the past few years, many researchers have accomplished scientometric analysis in several research domains. A sci- entometric research of data in Precision Medicine with an emphasis on oncology was conducted. The research con- cluded that 2005 was a breakthrough period, with the rate of growth exceeding 86-11 publications annually over the three years prior. “Western Europe” and “Northern America” contributed to 80% of global production [22]. this author [23] describe CASCAM, a systems-based framework that uses machine learning and bioinformatics to assess and determine the best representative cancer models for precision medicine.

Its congruence assessment measures the degree of concordance between human tumors and models, including xenografts, patient-derived organoids, and cell lines, guaranteeing model applicability in circumstances that are specific to a given pathway. Dipak D. Gadade et al. [24]

examine the use of ge- netic, epigenetic, protein, and metabolic biomarkers in cancer diagnosis, treatment, and prognosis. Although it emphasizes the potential of biomarkers to enhance treatment outcomes and reduce toxicity, it also focuses on the obstacles that have prevented the adoption of personalized medicine, such as tumor heterogeneity, cost constraints, and resistance to targeted medicines. The author of this paper examines how genetic screening and genetic medications treat cardiovascular diseases. Jo Nijs et al. [25] provide early indications that analgesics with a centralized effect could mitigate the risk of chronic postoperative pain in high-risk patients with central sensitization symptoms before surgery. The results in this study open up novel therapy solutions, including possibilities of precision pain medicine treatment that relies on pain phenotyping in rheumatology treatment. Edison ong et al.

[26] present an overview of ontological resources for the discipline of nephrology, which the nephrology community has not widely utilized. The results establish a framework for predicting individual requirements and identifying the appropriate treatment for individual patients. DSW Ho et al. [27] propose a general review of machine learning and polygenic risk scoring for challenging disease risk assessment. This study indicates how machine learning approaches can enhance complicated medical conditions prediction, allowing for the adoption of genetic information into upcoming per- sonalized healthcare. Fernando Soto et al. [28] discuss the latest developments in the field of micro and Nanorobotics for treatment, surgical procedures, diagnosis, and medical imag- ing. Dean Ho et al. [29] emphasize significant technological developments that contribute to personalized and precision medicine objectives and ongoing issues that provide the ability to recognize and track diseases and adequately determine the optimal drugs (chemotherapy, nanotherapy, etc.) Dhanusha A. Nalawansha et al. [30] emphasized the benefits associated with PROTACs (proteolysis-targeting chimera). They explored the recent chemical E3 ligases to enhance the collection of innovative E3 ligases that maximize TDPs (targeted protein degradation). Dainis et al. [31], the author of this paper, examines how genetic screening and genetic medications treat cardiovascular diseases. It concluded that new technologies and datasets provide more potential for making strides towards cardiovascular disease.

III. Research Objectives

The key objective of this study is to provide a quantitative evaluation of several facets of precision medicine research for the time period of 2013 to 2022. This study bases its findings on scientometric analysis, which examines the pub- lication developments, significant contributions, citations, and collaboration, and the co-occurrence of keywords in precision medicine research. Specifically, the purpose of this research is to analyze the:

- publication growth
- major contributions such as subjects' categories, geo- graphical distribution, and authors' productivity
- citation pattern of documents and influential journals
- Identify the most prominent institutions

- recognize the research hotspots, trends, and research gaps in the field of precision medicine.

IV. Research Methodology

In this investigation, we used a systematic approach to data collection and analysis. First, we gathered data from the Web of Science that spans from 2013 to 2023. Subsequently, we utilized the VOSviewer tool for visual analysis of the collected data. Our analysis encompassed several key areas, such as pub- lication development, citation analysis, and country analysis. Furthermore, we synthesized the information extracted from these analyses to draw comprehensive conclusions. Figure 2 illustrates the methodology of our research.

A. *Dataset collection*

This article performs a bibliographic analysis on precision medicine for publications from 2013 to 2022. Bibliometric analysis evaluates the data from publications to identify the scientific findings of various entities. Bibliometric analysis represents well-known tools for measuring and analyzing the publications in a scientific field of interest. The data for this analysis were collected from the database: Clarivate Analytics' Web of Science, which comprises the primary sources for citation data and, therefore, frequently used in bibliometric analysis.

B. *Search Strategies*

The Researcher reviewed the most frequently used and tested string assortments to select the best keyword. The fol- lowing query was used to retrieve the data from the database: (”healthcare” AND ”precision medicine”) in the fields of ab- stract, title, and keyword. The total number of records retrieved throughout the search was 1352. This research included all the years from 1952 to 2023 and retrieved documents, including research articles and reviews.

V. Publication Developments Overview

A. *Publication Growth*

This section depicts the publication development for pre- cision medicine research in smart healthcare from 2013 to 2022. This research analysis determined the annual expansion of the research, which will assist in comprehending the pattern of scientific development across time. Fig 3 demonstrates the annual rise in precision medicine publications. Out of 1352 publications, there were only seven in 2013 and in 2014, there were double publications as compared to previous year. In 2015, there were a total of 31 publications, which was a slight improvement over prior years. Following this, there was a surge in the field of precision medicine research, with 109 publications in 2016. The growth of publications was once again less for the years 2017 and 2018 than in previous years. Another turning point was attained in the year 2019 with 203 publications and the trend continued upward to 219- 268 publications in the years 2020-2022. Table I depicts the annual growth rate and the percentage share of the research publications over years. The following eq. (1) is the formula for calculating the annual growth rate:

$$AGR = \frac{\text{Last term} - \text{Start term}}{} \times 100 \qquad (1)$$

Start term

According to the AGR, the total count of publications for pre- cision medicine has fluctuated over time. The annual growth rate for 2014 has grown as per the count of publications. AGR increased to 100% for 2014 and then slightly increased for the following year. The period with the greatest AGR was in 2016, when the rate was more than doubled to 251.61% then dropping the following year. The AGR emerged again in 2019 to attain 37.16%, but dropped again in the following two years while emerging to 21.27% in 2022. The variations in the AGR are prompted by the erratic increase in publications throughout the time.

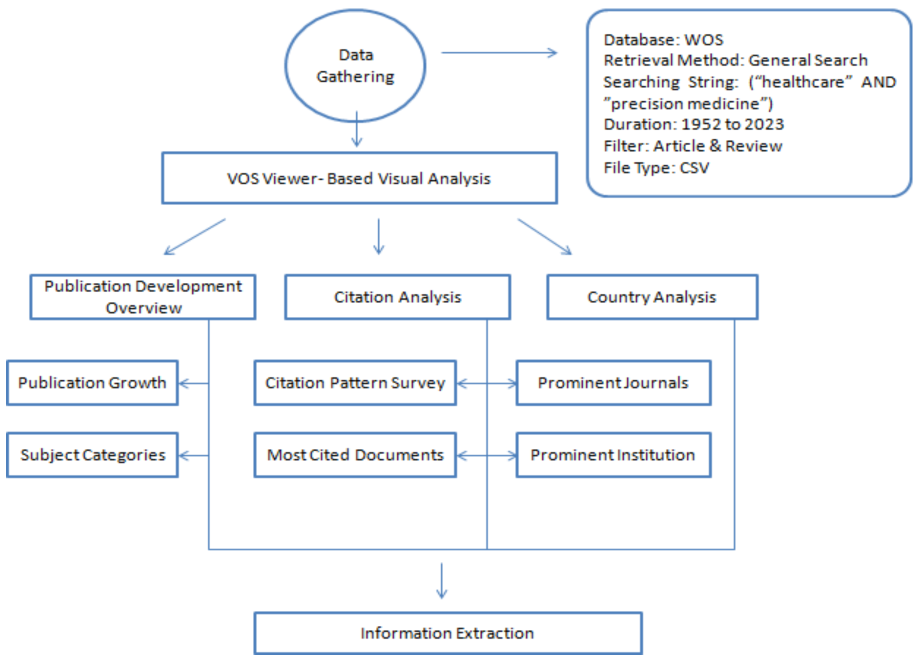

Fig. 2. Illustration of research methodology.

V. Subject Categories

The research of precision medicine falls under several subject categories. Figure 4 depicts the expanded categories of subjects in which precision medicine research is conducted. The analysis is conducted using the count of articles collected from the web of Science database. The analysis provides a percentage stake for several fields of precision medicine research. The top influential subjects are genetics & heredity and healthcare science & services, having highest count of publications 133 and 117, respectively, followed by oncology, pharmacology & pharmacy, Medicine, General & Internal, Medical informatics and Biochemistry & Molecular Biology having a count of 116, 114, 74, 58 and 51, respectively

TABLE I: ANNUAL GROWTH RATE OF PUBLICATIONS

Publication Years	No. of Publications	AGR
2013	7	-
2014	14	100.00
2015	31	121.43
2016	109	251.61
2017	132	21.10
2018	148	12.12
2019	203	37.16
2020	219	7.88
2021	221	0.91
2022	268	21.27

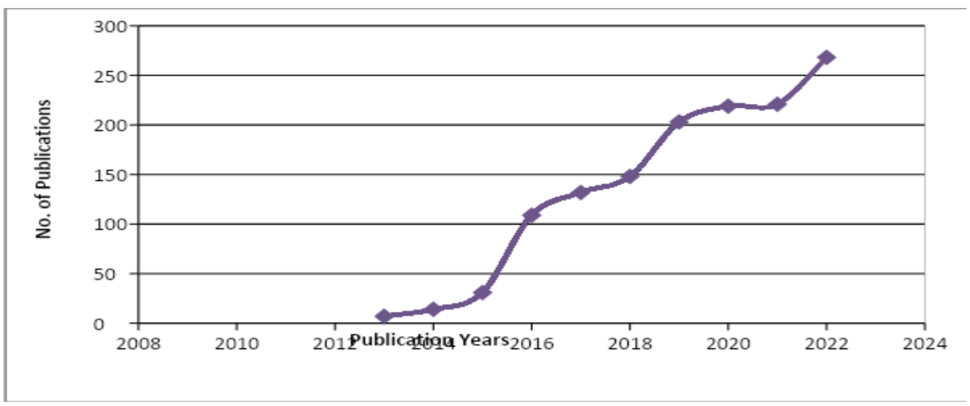

Fig. 3. Growth in Publications Over Time.

Cardiac & Cardiovascular systems, Medicine, Research & Ex- perimental, and Computer Science, and Information Systems have a total contribution of 45, 41 and 32 followed by Clinical Neurology having a contribution of 29. Biotechnology & Ap- plied Microbiology, Social Sciences, Biomedical, and Medical Ethics have a total contribution of publications are 29, 27, 24 followed by Immunology 24. These subjects provide minimal but significant contributions. The analysis demonstrates that this research area is dispersed throughout various topics with a variety of applications rather than confined to a single domain.

VI. CITATION ANALYSIS

This following section depicts the citation patterns. The cita- tion analysis tool counted the frequency with which the article was cited in other articles to assess the impact of publication or author. Although the citation has been examined, it has been found that it is insufficient to evaluate itself the importance of publications. Therefore, index of normalized citation impact is utilized to assess the impact of publications based on their longevity through the years. The NCII is summarized as a ratio of aggregated citations for each publication and longevity of publications.

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VII. Most Cited Documents

The data collected through the Web of Science illustrates the ratio of citations occurrence per publication. The following section highlights the most impacted articles from research publications from 2013 to 2022 based on citation. Table II depicts the top cited articles with their rank, article title, authors, journal title, publication year, citation, longevity and NCII in precision medicine research containing citation 150. This table shows that the article "Deep Learning in Medical Imaging: General Overview" (5) published in the journal named "KOREAN JOURNAL OF RADIOLOGY" has the highest citation number. This paper presents viewpoints on the advancements of deep learning technology, focusing on medical imaging. In this paper, the researcher introduced deep learning from a radiology perspective. In some computer vision and audio identification applications, deep learning has demonstrated superior results than humans. The second most cited paper in the table is "Sex and Gender: modifiers of Health, disease, and Medicine" (7) published in the journal "LANCET". The article addresses the fundamental effects of sex and gender as moderators of the leading causes of disease and death. The researcher's goal is to assist medical professionals to include sex and gender into their disease diagnosis and treatment techniques as an essential phase
towards precision medicine that may improve patient health.

A. *Prominent Journals*

According to the data analysis, the precision medicine is performed on total number of 25271citation demonstrating that the average number of citations for each publication is 18.69. The year 2017 has the highest number of citations and NCII, which indicates an immense raise for this year. The analysis comprised 1352 documents, of which 73 had minimum citation counts of 73, and the h-index is 73. H-index is a metric to quantifying an individual's contribution to scientific research [44]. The following section depicts the prominent journals in the field of precision medicine by analyzing the journal citation. Journals provide essential resources that have an impact on the framework of research. Therefore, determining a journal's impact on a research field is essential. Table III presents the information on the foremost journals with their citations. From 2013 through 2022, it demonstrates the journals with the highest number of citations in precision medicine research. This table includes the journal title, number of documents

TABLE II: Top Cited Documents in Precision Medicine Research

Title	Author	Source Title	Year	Total Citations	l	NCII
"Deep Learning in Medical Imaging: General Overview"	[5]	"KOREAN JOURNAL OF RADIOL- OGY"	2017	509	6	84.83333
"Sex and gender: modifiers of health, disease, and medicine"	[7]	"LANCET"	2020	475	3	158.3333
"Million Veteran Program: A mega-biobank to study genetic influences on health and disease"	[8]	"JOURNAL OF CLINICAL EPIDEMI- OLOGY"	2016	399	7	757
"Distribution and clinical impact of functional variants in 50,726 whole-	[9]	"SCIENCE"	2016	335	7	47.85714

exome sequences from the DiscovEHR Study”						
“Treatment patterns and direct medical costs of metastatic colorectal cancer patients: a retrospective study of electronic medical records from urban China”	[15]	“JOURNAL OF MEDICAL ECONOMICS”	2020	330	3	110
“Genetic analyses of diverse populations improves discovery for complex traits”	[11]	“NATURE”	2019	328	4	82
“Recommendations for the use of next-generation sequencing (NGS) for patients with metastatic cancers: a report from the ESMO Precision Medicine Working Group”	[16]	“ANNALS OF ONCOLOGY”	2020	314	3	104.6667
“Building the foundation for genomics in precision medicine”	[10]	“NATURE”	2015	281	8	35.125
“Precision Medicine: From Science To Value”	[32]	“HEALTH AFFAIRS”	2018	244	5	48.8
“FGFR inhibitors: Effects on cancer cells, tumor microenvironment and whole-body homeostasis (Review)”	[33]	“INTERNATIONAL JOURNAL OF MOLECULAR MEDICINE”	2016	228	7	32.57143
“Molecular profiling for precision cancer therapies”	[34]	“GENOME MEDICINE”	2020	225	3	75
“A perfect storm: How tumor biology, genomics, and health care delivery patterns collide to create a racial survival disparity in breast cancer and proposed interventions for change”	[35]	CA-A CANCER JOURNAL FOR CLINICIANS	2015	202	8	25.25
“Big data analytics to improve cardiovascular care: promise and challenges”	[36]	“NATURE REVIEWS CARDIOL- OGY”	2016	191	7	27.28571
“Convergence of Implementation Science, Precision Medicine, and the Learning Health Care System A New Model for Biomedical Research”	[37]	“JAMA-JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION”	2016	191	7	27.28571
“Medicine in the early twenty-first century: paradigm and anticipation - EPMA position paper 2016”	[38]	“EPMA JOURNAL”	2016	186	7	26.57143
“Promise of personalized omics to precision medicine”	[39]	“WILEY INTERDISCIPLINARY REVIEWS-SYSTEMS BIOLOGY AND MEDICINE”	2013	174	10	17.4
“Implementing Pharmacogenomics in Europe: Design and Implementation Strategy of the Ubiquitous Pharmacogenomics Consortium”	[40]	“CLINICAL PHARMACOLOGY & THERAPEUTICS”	2017	171	6	28.5

"The Role of 3D Printing in Medical Applications: A State of the Art"	[41]	"JOURNAL OF HEALTHCARE EN-GINEERING"	2019	165	4	41.25
"What is precision medicine?"	[42]	"EUROPEAN RESPIRATORY JOUR- NAL"	2017	160	6	26.66667
"Health Disparities and Triple-Negative Breast Cancer in African American Women"	[43]	"JAMA SURGERY"	2017	160	6	26.66667

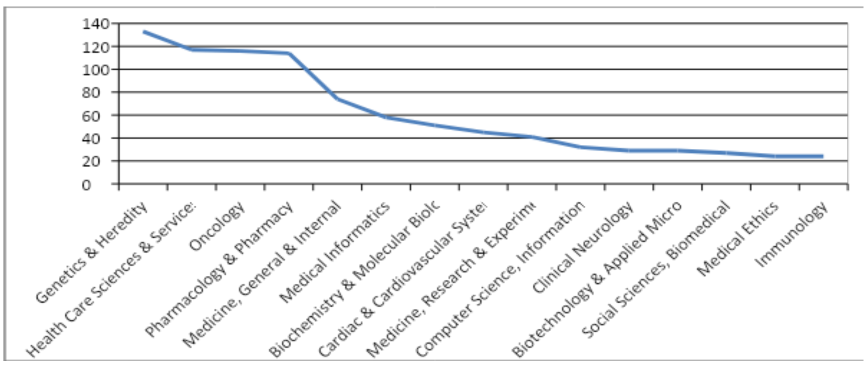

Fig. 4. Research Subject Categories in Precision Medicine Research.

(nf), number of citations (cf), the impact factor of the journal, the ratio of documents to articles, and percentage share of publications. The Impact factor is a widely used tool that is recorded in the journal citation report each year. The impact factor of a journal is computed using the numerator and denominator, which is the number of citations to any articles published in the journal in the current year and the number of significant articles published in the same two years. The top journal with citation counts of more than 190 are presented in Table 3. From 2013 to 2022, it represented the most cited journals in the precision medicine research field. The journal "Lancet" has the most citations, 505, and the number of articles having 505 citations per publication is 1, with a publication share of 0.073964. The impact factor of this journal is 38.927. The second journal, "Genetics in medicine," has the second highest counts of citations, 428, with an article count of 14, and has a 3.57143 ratio of citations to publication.

The % share of the following journal is 1.035503, and the impact factor is 8.864. The third journal has the highest citation count, "The Journal of clinical epidemiology," having a citation count of 415 with 2 articles and a ratio of citations to publication is 52.14286 and a percentage share of 0.147929. Another publication with a high impact factor and article count is "ca-a cancer journal for Clinicians (286.13, 1)", followed by "science (63.832, 1)", "nature reviews cardiology (49.421, 1)" and "lancet (38.927, 1)". Therefore, it is evident that the frequency of articles in that journal has zero impact on the number of citations, as a journal with a single publication may have the highest number of citations.

B. *Prominent Institution*

The following section focused the analysis on organizations involved in precision medicine initiatives. Using WoS results, this research found the institutions with the most influence in the field of precision medicine through the analysis of their citations that identifies the highly cited institutes associated with certain fields of research that may assist the researchers. Thus, it is essential to utilize citation information for analyzing the impact of institutions. Another metric for quantifying an individual's contribution to scientific research is the H- index [45]. Table IV provides a list of institutions involved in precision medicine research based on citations from 2013 to 2022. All the institutions with more than 550 citations are included in this table. According to the table, Harvard medical school (1892) of the United state has the highest number of citations, followed by ”Stanford University” (1504) of Califor- nia, ”university California sanfransico” (1320) of California, ”duke university” (1271) in North Carolina, ”university of colorado” (1173) of unite4d state, ”Harvard university” (1135) of united state, ”Brigham and Women's Hospital” (1044) of united state and ”Vanderbilt university” (976) of united state. This analysis also determined that cited institutions are from the United state (18), California (2), North Carolina (1), Sweden (1), and Switzerland (1). The finding shows that the most prominent institutes in precision medicine are from the United States.

VIII. Country Analysis

The following section examines country collaboration for precision medicine from 2013 to 2022 utilizing the visualizing tool VOSviewer. It demonstrates how the country connects with the regions associated with precision medicine. The analysis approach employed in this analysis is co-authorship, and the unit of analysis is countries using a comprehensive counting approach. The minimum number of citations was fixed at 5, and the result was 92 different countries have

TABLE III: Leading Journals in Precision Medicine Research

Source	nf	cf	IF	cf/nf	%share
“lancet”	1	505	38.927	505	0.073964
“genetics in medicine”	14	428	8.864	30.57143	1.035503
“journal of clinical epidemiology”	2	415	7.407	207.5	0.147929
“American journal of medical genetics part c-seminars in medical genetics”	77	365	2.83	52.14286	0.517751
“Science”	1	339	63.832	339	0.073964
“nature reviews cardiology”	3	332	49.421	110.6667	0.221893
“journal of allergy and clinical immunology”	3	325	14.29	108.3333	0.221893
“clinical pharmacology & therapeutics”	10	285	5.24	28.5	0.739645
“lancet”	1	281	38.927	281	0.073964
“genome medicine”	4	275	6.083	68.75	0.295858
“health affairs”	1	254	5.39	254	0.073964
“jama-journal of the American medical association”	2	252	157.3	126	0.147929
“journal of translational medicine”	8	228	7.71	28.5	0.591716
“briefings in bioinformatics”	5	210	13.994	42	0.369822
“ca-a cancer journal for clinicians”	1	203	286.13	203	0.073964
“bmc medical ethics”	8	201	2.77	25.125	0.591716
“personalized medicine”	22	199	3.508	9.045455	1.627219
“wiley interdisciplinary reviews-systems biology and medicine”	2	193	45.8	96.5	0.147929

"ieee transactions on biomedical engineering"	2	192	4.756	96	0.147929
"journal of medical internet research"	15	191	7.077	12.73333	1.109467

TABLE IV: KEY RESEARCH INSTITUTIONS IN PRECISION MEDICINE RESEARCH

Organization	Documents	Citations	Countries	c/p	%share
"Harvard Medical School"	56	1892	"United States"	33.78571429	4.142011834
"stanford university"	45	1504	"California"	33.42222222	3.328402367
"University California San Francisco"	38	1320	"California"	34.73684211	2.810650888
"duke university"	34	1271	"North Carolina"	37.38235294	2.514792899
"University of Colorado"	16	1173	"United States"	73.3125	1.183431953
"Harvard University"	12	1135	"United States"	94.58333333	0.887573964
"Brigham and Women's Hospital"	21	1044	"United States"	49.71428571	1.553254438
"Vanderbilt University"	34	976	"United States"	28.70588235	2.514792899
"University of Texas Health Science Center"	8	927	"United States"	115.875	0.591715976
"Johns Hopkins University"	25	893	"United States"	35.72	1.849112426
"Karolinska Institute"	17	873	"Sweden"	51.35294118	1.25739645
"University of Washington"	28	821	"United States"	29.32142857	2.071005917
"Icahn School of Medicine at Mount Sinai"	19	771	"United States"	40.57894737	1.405325444
"University of North Carolina"	22	701	"United States"	31.86363636	1.627218935
"University of Zurich"	9	681	"Switzerland"	75.66666667	0.665680473
"University of Michigan"	25	664	"United States"	26.56	1.849112426
"National Human Genome Research Institute"	15	642	"United States"	42.8	1.109467456
"University Chicago"	14	634	"United States"	45.28571429	1.035502959

published their research publications in precision medicine. The country participation mesh of precision medicine is represented in Figure 5 by a total of 52 nodes and 666 links. The node size represents how many documents it contains, and links imply the relationships between different countries. Color symbolizes the similar cluster; the node colors in a cluster are identical. Links and total links strength are employed to identify the co-authorship between countries. The link represents the count of co-authorship relations of a specific author with another author, and TLS identifies the overall co- authorship strength links of an author with some other author [46]. According to the figure 5, it observed that the country "united States" has highly published documents 699 with total link strength of 511, followed by the country "England" with total articles 155 and total link strength of 396, "Italy" (127), "Germany" (106), "Canada" (101), "Netherlands" (71) and "Spain" (71) with the total link strength 321, 343, 208, 228 and 302 respectively. As a result of the analysis, these countries with the highest number of links are designated as the main hub for collaboration in the field of precision medicine research.

IX. THE RESEARCH HOTSPOT AND TRENDS IN PRECISION MEDICINE

The following section assesses the most widespread pre- cision medicine research topics from

2013 to 2022. The title of the article is intended to represent widely searched keywords. Different clusters of keywords are examined in order to determine the research hotspots. Clustering is used to collect keywords with the same topic of study. Utilizing keyword co-occurrences enables an investigation of keyword associations and the identification of research trends over time in publications. The keywords co-occurrences network is developed for the research hot spots in precision medicine. VOSviewer is employed to demonstrate the relations between different keywords and their co-occurrence (figure 6).

The very first batch (red color, cluster 1) has 23 associated keywords. This cluster focuses on ”artificial intelligence,””big data,” and ”bioinformatics.” The cluster’s core research interests are in technologies and diagnosis. The second batch (green color, cluster 2) has a 19-keywords co-occurrence network. This research focuses mostly on oncology, chemotherapy, and cell-lung cancer. A co-occurrence network that includes 18 keywords is emphasized in the third batch (blue color, cluster 3). Breast cancer, lung cancer, genetic testing, cardiovascular disease, and prostate cancer are some of the key research areas of this cluster. The fourth batch (yellow color, cluster 4) comprises a network of 16 keywords with co-occurrences that are associated with genetic disease. The cluster’s key research interests include schizophrenia, diabetes, Alzheimer’s disease, gut macrobiotics and rheumatoid arthritis. The last batch (purple color, cluster 5) has a network of co-occurring keywords that are related to personalized medicine and genomic medicine. The cluster’s primary research areas are precision medicine, genotyping, clinical implementation, genetic variation, and pharmacokinetics.

The keyword occurrence frequency (percentage) for Cluster 1 is presented in A “Big data” is forecast to provide for 13.15 percent share of the cluster, whereas “ai” have (11.21%) a segment of the cluster. Other major innovations in this cluster consist of ml (10.61%), dl (4.78%), and ehr with a share of (4.48%). Cluster 2 assessments across various keyword occurrences are demonstrated in B. Oncology, with an anticipated% share of 12.53%, is followed by asthma, with 6.68%, and double blind, with 6.12%. Additional contributors make a contribution to this cluster, including epidemiology (5.29%), cell lung cancer (4.73%), and chemotherapy, with a 4.17 percent com- mon breakdown. Cancer has the biggest break in the cluster (25.21%), determined by the percentage share of keyword occurrences in Cluster 3 in C. Other significant contributors to the cluster include breast cancer (9.50%), genetic testing (5.16%), and lung cancer (5.16%).

The percentile share of keyword frequencies in Cluster 5 is depicted in D. Genetics, representing a significant dispersion in the cluster with 19.22 percent. Others such as metabolomics (6.91%), omics (4.80%), and rheumatoid arthritis (4.20%), also contribute a significant impact to the cluster. E represents the percentage share of the keyword occurrences in the final Cluster 5. Personalised medicine has the most substantial split (36.29%) in the cluster. Additionally, the cluster has a noteworthy contribution from pharmacognostics (12.54%) following by genomic medicine (11.19%). Figure 6 represents the most prospective and recent developments in the domain of Precision medicine as identified by analysis of the network developed through keyword co-occurrences from 2013 to 2022. VOSviewer is used to generate a web of keyword co-occurrences based on the average problem year for every keyword. The essential terms for Precision medicine research are depicted by the nodes. The publishing year, the co-occurrence frequency and the connections between terms are all outlined by the node shades and range.

The similarities between the colors expand with the strength of the link across the nodes. The co-occurrences of the keywords are examined in order of identifying new trends depending on the publishing year. The nodes that are displayed in figure 7. With the typical publishing years of 2020 and 2019 illustrate how recently publications can be recognized by their yellow and green coloring. The most recent developments in precision medicine research encompass Big Data, genetic testing, targeted therapy, deep learning, machine learning and artificial intelligence. Cancer, oncology, asthma, chemotherapy, alzheimer's disease and genotyping are the most prevalent fields of precision medicine research for the average publications throughout the year 2018 and 2019.

X. Use Cases of Precision Medicine in Healthcare

Precision medicine is reshaping healthcare by enabling personalized approaches to disease prevention, diagnosis, and treatment based on individual genetic, environmental, and lifestyle factors. Below are some notable use cases of precision medicine across different medical fields.

A. Radiogenomics: AI-Powered Cancer Risk Prediction

Radiogenomics is a promptly expanding discipline in precision medicine that combines radiology and genomics to investigate the correlations between imaging findings and genetic abnormalities in cancer patients. Particularly, it seeks to improve individualized treatment regimens and predict cancer risks. Indeed, Radiogenomics has been deployed to correlate imaging abnormalities with core genetic alterations in order to estimate the potential impacts of unfavorable outcomes during radiotherapy (41) [47]. AI is additionally utilized to detect Radiogenomics correlations, notably for liver, breast, and colorectal cancer. Breast cancer, the most often diagnosed cancer in women and a primary cause of fatalities, demonstrates enormous variation in tumor amenities, prediction, and treatment responses [48]. Although breakthroughs in early detection through mammography have decreased breast cancer fatality rates, the integration of AI into Radiogenomics for breast cancer provides prospects for more accurate treatments. However, one of the key challenges in this domain remains the lack of accessible and high-quality data [49].

B. Digital Twin Technology in Healthcare: Cardiology Appli- cation

The notion of the digital twin, which originated in the industrial sector, is utilized in the medical field to create virtual patient models that can be used to simulate therapy regimens. In cardiology, a digital twin is evolved by combining genomic data and other health parameters to predict the outcomes of different treatment options. This model can be revised in real- time based on patient data, providing a constantly evolving simulation to assist with decision-making [50], [51]. A digital twin can be connected to the adjacent cluster group in a population-wide database, providing personalized insights that can inform patient care. Validating and enhancing simulated treatments with real-world patient outcomes improves the database for future usage [52]. This technology is rapidly being explored as a tool for optimizing complex medical pro- cedures, particularly in chronic disorders like cardiovascular diseases, where personalized interventions are critical.

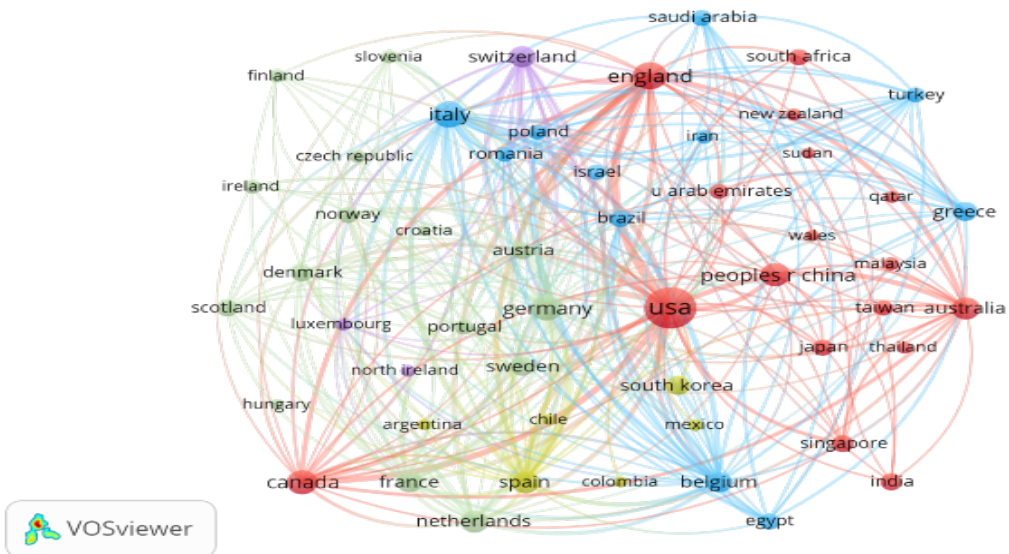

Fig. 5. Country Collaboration Network in Precision Medicine Research.

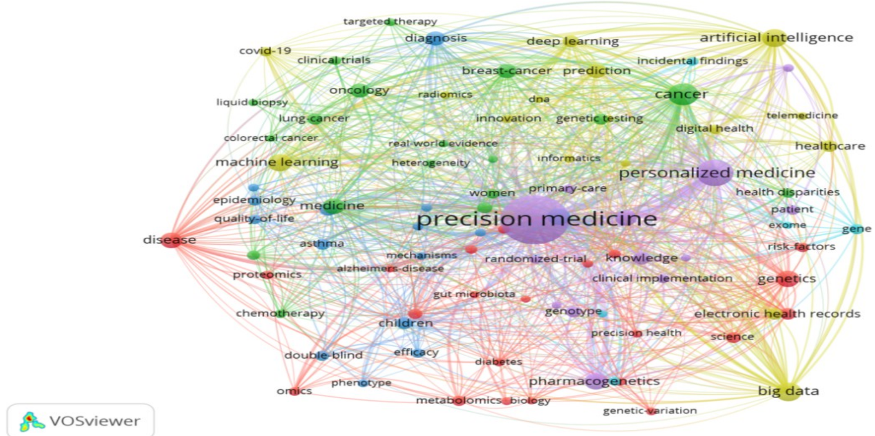

Fig. 6. Keyword Co-occurrence Map in Precision Medicine Research.

C. Precision Medicine in Lung Cancer Treatment

Lung cancer, particularly non-small cell lung cancer (NSCLC), has emerged as a revolutionary field for precision medicine. Throughout the past two decades, significant advancement has been achieved in figuring out the genomic and molecular cause of NSCLC [53]. Precision medicine represents a transition from traditional methods to more individualized treatment approaches by using massive amounts of data analytics to personalize treatments to the individual genetic identities of lung cancer patients. Whereas conventional imaging and pathology screening provides an important role in detecting lung cancer, it is incapable of meeting the complicated requirements of precision medicine [54]. AI technologies are becoming increasingly incorporated into diagnostic proce- dures, optimizing the accuracy and efficacy of imaging and pathology testing. AI demonstrates ability in pharmacological evaluation, where it anticipates an individual's response to certain drugs, enabling individualized treatment regimens that may mitigate adverse effects and enhance productivity [55], [56].

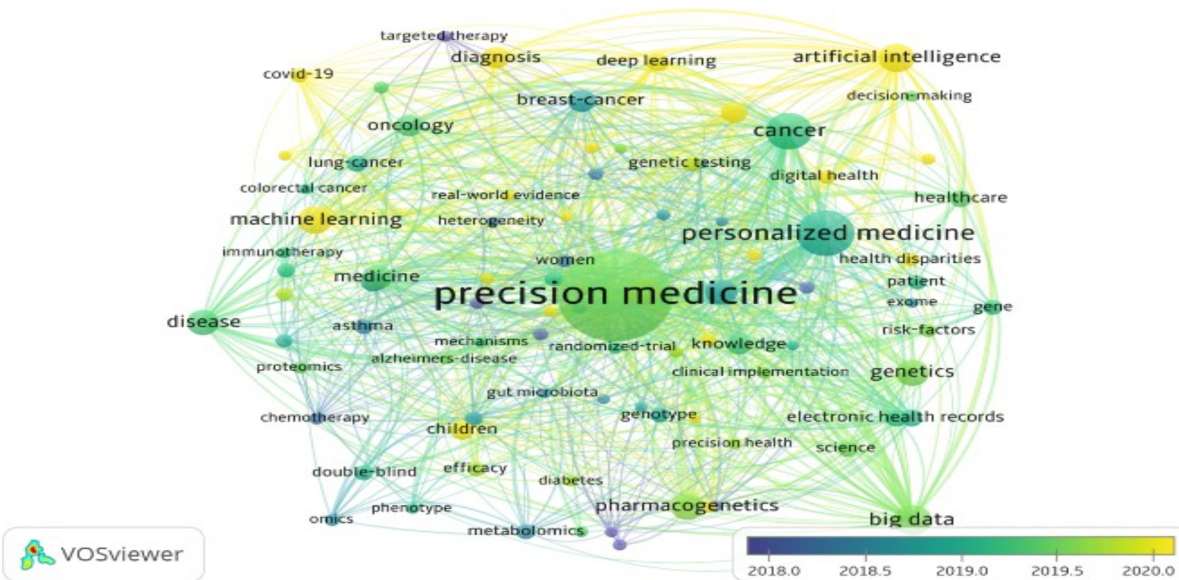

Fig. 7. Emerging Research Trends and Key Focus Areas in Precision Medicine.

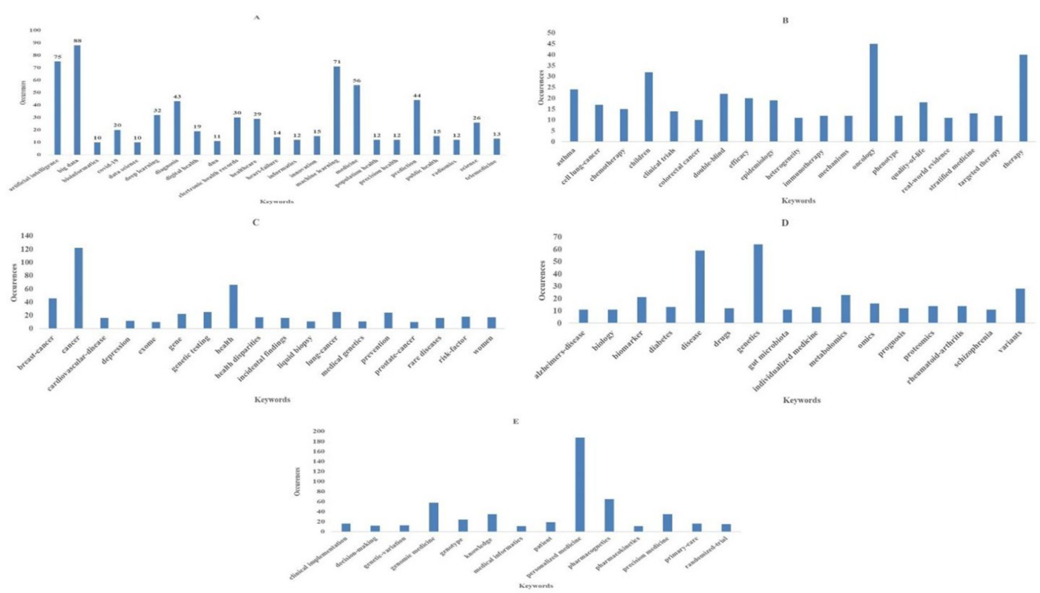

Fig. 8. Depicts the clusters of Precision Medicine Research (A). Technologies, (B). Oncology, (C). Cardiovascular disease, (D). Genetic disease, (E). Personalized medicine

XI. CONCLUSION

The research provides a quantitative and qualitative scientometric analysis of the scholarly literature on precision medicine through several analytical techniques. The purpose of this scientometric analysis was to provide an up-to-date overview of the current state of healthcare in precision medicine. It derived significant findings using scientometric techniques which will assist the academic community globally grasp the evolving scientific advancement from 2013 to 2022. This paper revealed several significant observations through this scientometric analysis. The field of research is quite new, having an explosive rise in citations and publications since 2019. The study illustrates a multitude of Bibliometric traits, including publication development patterns, citation visual- izations, most influential journals, and mapping of keywords co-occurrence. Genetics and healthcare science are the most significant areas in this discipline, which helps increase the number of publications and citations. The most recent trends in PM research are genomic medicine and genetic testing. Digital twins, Big Data, Deep Learning, Artificial Intelligence and Data Science are among the most recent study areas for Precision Medicine research. The future study may be explored further to expand on the discipline of precision medicine and identify novel directions based on the present findings.

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