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# Global Research Landscape of Artificial Intelligence in Urology: A Systematic Analysis of Emerging Trends, Clinical Impact, and Collaborative Networks (1971–2024)

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## Abstract

**Background:** Despite the rapid integration of artificial intelligence (AI) in urological practice, a comprehensive understanding of research evolution and impact patterns remains unexplored. This analysis provides a systematic examination of its scientific development and future potential.

**Methods:** We conducted a comprehensive analysis of AI-related urological publications through October 2024 using the Scopus database. The study incorporated English-language original articles and reviews, utilizing VOSviewer, GraphPad Prism, and Data Wrapper for analysis and visualization.

**Results:** Our investigation encompassed 5755 publications, comprising 5109 original articles and 646 reviews, with 63.9% being open access. The field demonstrated exponential growth from a single publication in 1971 to 1337 publications in 2024, garnering 112,583 citations. The past decade has witnessed the emergence of the most influential articles, particularly those focusing on deep learning (DL) applications in urological cancer detection. The USA-led global contributions (31.1%), followed by China (23.7%) and India (8.2%). "Scientific Reports" emerged as the leading journal with 171 publications. Titles and abstracts analysis revealed key focuses on DL in imaging (n = 1067), chronic kidney disease (n = 801), and advanced DL methodologies (n = 794). The keyword analysis identified "machine learning" as the dominant theme (1331 occurrences), with "prostate cancer" (955) and "deep learning" (838) following closely. Contemporary trends show significant shifts toward ChatGPT applications, pharmacovigilance, and AI-assisted surgical planning. In terms of international collaboration, the USA demonstrated the strongest network with a link strength of 1543.

**Conclusion:** This study traces AI's evolution in urology, from basic ML to advanced clinical tools, with particular advancement in radiomics, imaging, and biomarker analysis. Successful future implementation necessitates addressing ethical considerations, technical hurdles, and practical challenges while maintaining focus on patient safety and equitable healthcare access.

**Keywords:** Artificial Intelligence, Machine Learning, Deep Learning, Urology, Prostate Cancer, Bladder Cancer, Trend Analysis, Bibliometric, Scientometric

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***↑What is "already known" in this topic:***
Artificial intelligence (AI) applications are increasingly being integrated into urological practice across various domains, including imaging analysis, diagnostics, and treatment planning. Several studies have examined specific AI applications in urology, but a comprehensive understanding of the overall research landscape and evolution remains limited.

***→What this article adds:***
This bibliometric analysis provides the first comprehensive overview (1971-2024) of AI research trends in urology, identifying key contributors, emerging focus areas, and collaboration networks. It reveals the evolution across three distinct time periods, showing the shift from basic neural networks to sophisticated applications in radiomics, pharmacovigilance, and robotics. The study highlights emerging areas, including ChatGPT applications, FAERS, dose prediction, and AI-assisted surgical planning, while mapping the transition from fundamental machine learning (ML) to advanced clinical tools in imaging analysis, biomarker identification, and chronic kidney disease management, offering valuable insights into the current state and future directions of AI in urological practice.

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## Introduction

Urology, a medical specialty addressing urinary tract and male reproductive disorders, encompasses diverse conditions from infections to urological cancers, significantly impacting healthcare outcomes (1, 2). Artificial intelligence (AI) is increasingly transforming healthcare, with urology emerging as a particularly promising field for AI applications in diagnostic imaging, treatment planning, and surgical guidance (3). AI algorithms can analyze imaging data to detect malignancies more accurately than traditional methods, aiding therapeutic decisions and predicting surgical outcomes effectively (4, 5). Machine learning (ML) and deep learning (DL) are revolutionizing urology by enabling personalized treatment plans that optimize outcomes for various urological conditions (6).

Bibliometric analysis provides a quantitative framework for evaluating scientific literature, enabling researchers to map research evolution, citation patterns, and scholarly collaborations (7, 8). In the context of urology and AI, such analyses can illuminate technological integration, identify key research contributions, and reveal critical knowledge gaps. Existing reviews have primarily focused on specific urological conditions or individual AI technologies, creating fragmented insights across the field. Previous studies have presented conflicting perspectives on the clinical readiness of AI applications in different urological domains, while comprehensive mapping of research collaboration patterns remains unexplored.

Despite the growing interest in AI applications for urological conditions, comprehensive studies covering the intersection of all urological diseases with AI are lacking. This bibliometric analysis addresses these gaps by providing the first comprehensive quantitative synthesis across all urological subspecialties, resolving conflicting findings about research maturity, and identifying collaboration opportunities. Therefore, this study aims to conduct an extensive bibliometric analysis, to identify trends and influential works, and to guide future research, ultimately enhancing the understanding of AI's role in urology.

## Methods

### *Search Strategy and Data Sources*

The present investigation employed Scopus as the principal bibliometric database, owing to its established advantages in academic document indexing and citation analysis capabilities. The database selection was informed by several critical factors, including its extensive coverage of peer-reviewed publications, sophisticated citation monitoring systems, and comprehensive bibliometric data extraction features (9). A systematic search protocol was implemented on October 14, 2024, which incorporated the complete temporal span of the database from its establishment. The search methodology incorporated an extensive array of standardized Medical Subject Headings (MeSH) and field-specific terminology pertaining to urological disorders and related clinical entities. The search methodology incorporated an extensive array of standardized Medical Subject Headings (MeSH) and field-specific terminology related to urological disorders and associated clinical entities. To ensure comprehensive coverage, the search strategy encompassed multiple linguistic variations, synonyms, and alternative spellings of key terms. The complete search algorithm and Boolean operators utilized in this investigation were documented in detail within the Appendix. To ensure methodological rigor and maintain analytical consistency, the investigation parameters were confined to peer-reviewed publications in English, explicitly focusing on original research articles and reviews while excluding other publication categories and non-English manuscripts.

### *Data Collection and Processing*

Data extraction proceeded in two phases. First, we exported the complete dataset in CSV format covering the entire timespan from inception to the search date. To investigate the temporal evolution of author keywords and identify emerging research themes, the timeline was divided into three periods: 1971-2000 (comprising 12 years of actual publications within this timeframe), 2001-2012, and 2013-2024. This division allows for a detailed view of trends across distinct eras.

The bibliometric data, exported in CSV format, included details such as document titles, authors, affiliations, keywords, publication years, document types, citations, sources, and abstracts.

### *Analysis Methods and Visualization Techniques*

Our analytical approach combined multiple bibliometric techniques and visualization methods. The bibliometric data underwent thorough processing and analysis using Microsoft Excel for primary data management. We analyzed citation counts, leading authors, institutions, countries, journals, and influential publications. Annual publication and citation trends were visualized with line graphs using GraphPad Prism (Version 9.5.1). For network analysis, we employed VOSviewer (version 1.6.20) (10) to map the relationships between terms, author keywords, countries, authors, and sources. In the VOSviewer analyses, we implemented specific occurrence thresholds for various network analyses, including co-authorship networks, country collaborations, keyword co-occurrences, and bibliographic coupling. These thresholds were carefully determined through iterative testing to achieve an optimal balance between comprehensive representation and analytical clarity.

Using these parameters, we generated three types of visualizations: network, overlay, and density. Network visualizations elucidated various bibliometric relationships, including international country collaborations, au-

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thor co-authorship networks, keyword co-occurrences, and term co-occurrences. The spatial arrangement of elements reflected their interconnectedness, with proximal items signifying stronger relationships. Element significance was denoted by node and label size, while inter-node connections represented relationship strength. A clustering algorithm categorized related items, assigning distinct colors to different clusters based on their network associations. To visualize temporal patterns in research topics, we utilized VOSviewer's overlay visualization feature for co-occurring author keywords. This technique applied a color gradient to the network, with colors ranging from blue (earlier publications) to yellow (more recent publications). This approach allowed us to observe the distribution of research topics over time in the field of urology and AI. In the visualization, the node size represents the frequency of each keyword, and the color indicates the average publication year associated with that keyword. Density visualizations were employed to analyze bibliographic coupling among journals and the temporal evolution of research topics. A rainbow density map elucidated areas of strong bibliographic connections between journals. To examine the progression of research themes, item density visualizations were generated for author keywords across three distinct periods. In these visualizations, the juxtaposition of cooler (blue) and warmer (yellow) color regions indicates the emergence of novel research areas alongside established topics, offering insights into the dynamic landscape of urology and AI research.

Lastly, the geographical distribution of research contributions was illustrated using Data Wrapper, providing a comprehensive view of global research patterns.

## Results

### *Publication Characteristics and Subject Area*

In this bibliometric analysis, 8,284 records were initially retrieved, with 5755 relevant publications selected after excluding nonoriginal, non-review, and non-English language articles. Among these, 5109 (88.7%) were original research articles, while 646 (11.3%) were review papers. A significant portion of the publications, 3670 (63.9%), were open access, highlighting the trend of increasing accessibility to global research. The international research output in this field has been published across 21 different subject areas. The subject areas of publications are as follows: Medicine (n = 3763), Biochemistry, Genetics and Molecular Biology (n = 1480), Computer Science (n = 1204), Engineering (n = 760), Health Professions (n = 365), Multidisciplinary (n = 305), Mathematics (n = 276), Physics and Astronomy (n = 266), Chemistry (n = 253), Materials Science (n = 208), Chemical Engineering (n = 184), Pharmacology, Toxicology and Pharmaceutics (n = 148), Immunology and Microbiology (n = 147), Neuroscience (n = 97), Nursing (n = 77), Agricultural and Biological Sciences (n = 69), Environmental Science (n = 66), Decision Sciences (n = 55), Business, Management and Accounting (n = 38), Social Sciences (n = 33), Energy (n = 15), Earth and Planetary Sciences (n = 14), Arts and Humanities (n = 11), Veterinary (n = 11), Psychology (n = 9), Dentistry (n = 8), Economics, Econometrics and Finance (n = 3).

### *Annual Publication Trends*

The analysis of publication trends over the years reveals a clear upward trajectory in the number of articles published. Starting with just one publication in 1971, there was steady but slow growth in subsequent years, followed by a remarkable surge beginning in the late 2010s. This increase is particularly pronounced in recent years: from 478 publications in 2020, rising to 675 in 2021, and further to 897 in 2022. This trend continued with 1202 publications in 2023 and reached 1,337 in 2024. This significant growth, as illustrated in Figure 1 a, underscores the escalating interest in the field over the past few years.

### *Annual Citation Trends*

The cumulative citations for these works amounted to 112,583, indicating a substantial impact of this body of research on the scientific community. Initially sparse in earlier years, citations surged to 7597 in 2020, rose sharply to 12,971 in 2021, and further increased to 18,091 in 2022. In 2023, citations reached 24,315, followed by an additional increase to 25,877 in 2024, showcasing the growing impact and relevance of research within this domain (Figure 1 b).

### *Most Influential Publications*

The analysis of the most cited articles indicates that the majority of these publications have emerged within the last decade, highlighting the increasing integration of AI in medical applications. The leading article is by Campanella et al (2019), titled "Clinical-grade computational pathology using weakly supervised DL on whole slide images," which has garnered 1398 citations, averaging 279.6 citations per year. This study presents an AI system capable of analyzing pathology slides for cancer detection without the need for manual annotations (11). Following closely is Hamet et al (2017) with their review article "AI in medicine," which has received 1308 citations (186.8 average citations per year). This review discusses various AI applications in medicine, focusing on both virtual systems—such as medical informatics and decision support—and physical systems like surgical robots and nanorobots (12). The third most cited article is "Serum protein fingerprinting coupled with a pattern-matching algorithm distinguishes prostate cancer from benign prostate hyperplasia and healthy men" by Adam et al (2002). This research has been cited 877 times (39.8 average citations per year) and utilizes AI and mass spectrometry to identify protein patterns in blood serum for early prostate cancer detection (13). The remaining articles in the top ten list provide insights into AI applications in urology, as shown in Table 1. Analysis reveals a strong focus on DL and neural networks, particularly in pathology image analysis and automated diagnostics, highlighting the field's shift toward advanced ML architectures. The Lancet Oncology appears multiple times, with notable studies by Bulten et al (14) and Strom et al (15), on AI-based automated Gleason grading for prostate cancer.



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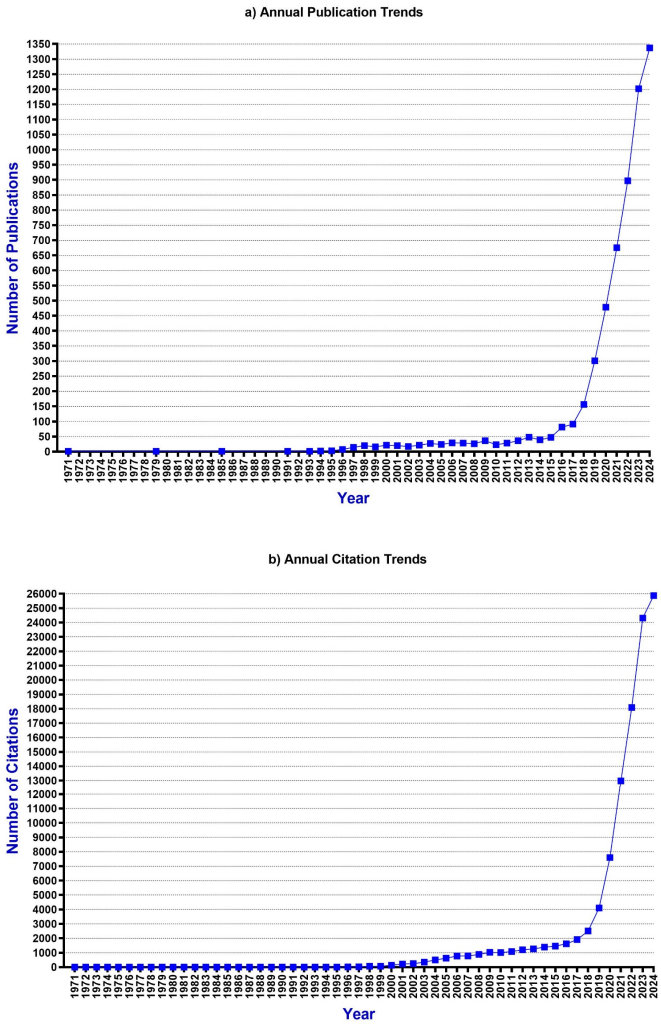


*Figure 1.* Annual trend in published studies (a) and citations (b) on urology and AI

### *Top Countries, Geographic Distributions, and International Collaborations*

The analysis of countries with the highest contributions highlights significant global engagement. The United States of America (USA) leads with 1792 publications (31.1%), followed by China with 1,365 (23.7%) and India with 476 (8.2%). Together, these three countries account for 63% of all publications. The information on the top ten contributing countries is presented in Table 2. The geographical distribution map in Figure 2 a illustrates that North America and East Asia are prominent regions, with the USA, China, and India leading in contributions. European countries also demonstrate strong participation, while Australia contributes significantly as well. In South America, Brazil, Chile, and Colombia are notable contributors in this field. However, very few countries from Africa have participated in this area, with Egypt, South Africa, Nigeria, and Ethiopia representing the most active contributors from the continent. In contrast, there is noticeable participation among countries in the Middle East, indicating some level of engagement in research related to urology and AI. In terms of co-contribution among countries, the analysis identified 57 countries that met the threshold of at least 10 documents published on this topic. The total link strength for these collaborative efforts reached 5594, illustrating significant international cooperation in research related to urology and AI. The USA led with a link strength of 1543, followed by the UK (n = 741), Germany (n = 592), and Italy (n = 562). China (n = 530), Canada (n = 514), the Netherlands (n = 423), Australia (n = 401), France (n = 383), and Spain (n = 359) also showed notable contributions (Figure 2 b).

### *Influential Journals and Bibliographic Coupling Analysis*

Among the top journals in this bibliometric analysis, Scientific Reports led with 171 contributions, accounting for 2.9% of total publications. Cancers followed with 123 publications (2.1%), and Frontiers in Oncology contributed 110 publications (1.9%). While these journals lead in publication count, their combined contributions represent



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*Table 1.* The 10 Most Cited Articles in AI and Urology Studies

| # | Authors | Year | Article Title | AI Approach | No. of Citations | Average Citations per Year | Article Type | Journal Title | CiteScore* 2023 | IF* 2023 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Campanella et al | 2019 | Clinical-grade computational pathology using weakly supervised deep learning on whole slide images | AI system for analysis of pathology slides without manual annotations | 1398 | 279.6 | Article | Nature Medicine | 100.9 | 58.7 |
| 2 | Hamet et al | 2017 | Artificial intelligence in medicine | Overview of AI applications in medicine: virtual and physical systems | 1308 | 186.8 | Review | Metabolism: Clinical and Experimental | 18.9 | 10.9 |
| 3 | Adam et al | 2002 | Serum protein fingerprinting coupled with a pattern-matching algorithm distinguishes prostate cancer from benign prostate hyperplasia and healthy men | Using AI and mass spectrometry to identify protein patterns in blood serum for early prostate cancer detection | 877 | 39.8 | Article | Cancer Research | 16.1 | 12.5 |
| 4 | Litjens et al | 2016 | Deep learning as a tool for increased accuracy and efficiency of histopathological diagnosis | Deep learning application to automate cancer detection in pathology slides, focusing on prostate cancer and breast cancer metastasis | 793 | 99.1 | Article | Scientific Reports | 7.5 | 3.8 |
| 5 | Lu et al | 2021 | Data-efficient and weakly supervised computational pathology on whole-slide images | Development of a data-efficient AI system (CLAM) that learns to analyze pathology slides using only basic labels | 694 | 231.3 | Article | Nature Biomedical Engineering | 45.3 | 27.7 |
| 6 | Bulten et al | 2020 | Automated deep-learning system for Gleason grading of prostate cancer using biopsies: a diagnostic study | Development and validation of an AI system for automated Gleason grading of prostate biopsies | 419 | 104.7 | Article | The Lancet Oncology | 62.1 | 41.6 |
| 7 | Strom et al | 2020 | Artificial intelligence for diagnosis and grading of prostate cancer in biopsies: a population-based, diagnostic study | AI system development for automated prostate cancer detection and Gleason grading with expert-level accuracy | 374 | 93.5 | Article | The Lancet Oncology | 62.1 | 41.6 |
| 8 | Goodacre et al | 1998 | Rapid identification of urinary tract infection bacteria using hyperspectral whole-organism fingerprinting and artificial neural networks | Using AI neural networks with spectroscopic methods for rapid bacterial identification | 358 | 13.7 | Article | Microbiology | 4.6 | 2.6 |
| 9 | Yipeng et al | 2018 | Weakly-supervised convolutional neural networks for multimodal image registration | AI-based system for aligning multimodal medical images using anatomical labels | 329 | 54.8 | Original | Medical Image Analysis | 22.1 | 10.7 |
| 10 | Goldenberg S.L et al | 2019 | A new era: artificial intelligence and machine learning in prostate cancer | Overview of AI applications in prostate cancer management | 316 | 63.2 | Review | Nature Reviews Urology | 12.5 | 12.1 |

* CiteScore: A journal-level metric calculated by dividing the total number of citations received by documents published in a journal over a four-year period by the total number of citable documents (articles, reviews, conference papers, book chapters, and data papers) published in that same four-year period, as reported by Scopus. IF2023: Journal Impact Factor for 2023, calculated by dividing the total number of citations received in 2023 by articles published in the journal during the two preceding years (2021-2022) by the total number of citable articles published in those same two years, as reported by C

only a small fraction of the total, highlighting the diversity of other journals contributing to the literature. The complete list of the top journals and their respective publication counts is presented in Table 2. In our bibliometric analysis of journal bibliographic coupling, we considered sources with a minimum of 10 documents, resulting in a total of 116 sources meeting this threshold from an initial pool of 1550. The analysis revealed significant link strengths among various journals, indicating their interconnectedness based on mutual citations. The journal Cancers exhibited the highest total link strength of 33,273, with 123 documents and 1,234 citations, positioning it prominently within the network of related literature. Following closely is European Radiology, which has a total link strength of 22,274 from 69 documents and 1,936 citations. Scientific Reports ranked third with a total link strength of 22,080, comprising 171 papers and 4,581 citations. These journals demonstrate a high degree of bibliographic coupling, suggesting they share substantial subject matter in common. The full details of the top journals and their respective link strengths are presented in Table 3.

The rainbow density map in Figure 3 illustrates bibliographic coupling among journals, using color variations to represent the strength of connections or the number of shared references between them. Journals that exhibit a higher density of connections with other journals—



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*Table 2.* Top 10 Countries, Journals and Authors in AI and Urology Studies

| No. | Country | NP* (%) | Journal | NP (%) | Author | NP (%) |
|---|---|---|---|---|---|---|
| 1 | United States | 1792 (31.1) | Scientific Reports | 171 (2.9) | Turkbey B | 52 (0.9) |
| 2 | China | 1365 (23.7) | Cancers | 123 (2.1) | Somani B.K | 27 (0.4) |
| 3 | India | 476 (8.2) | Frontiers in Oncology | 110 (1.9) | Brooks J.D | 25 (0.4) |
| 4 | United Kingdom | 436 (7.5) | Medical Physics | 97 (1.6) | Madabhushi A | 25 (0.4) |
| 5 | Germany | 365 (6.3) | Diagnostics | 83 (1.4) | Edenbrandt L | 20 (0.3) |
| 6 | Italy | 328 (5.6) | European Radiology | 69 (1.1) | Checcucci E | 19 (0.3) |
| 7 | Canada | 321 (5.5) | Computers in Biology and Medicine | 68 (1.1) | Liu T | 19 (0.3) |
| 8 | South Korea | 247 (4.2) | IEEE Access | 66 (1.1) | Naik N | 19 (0.3) |
| 9 | Netherlands | 215 (3.7) | Plos One | 62 (1.0) | Stephan C | 19 (0.3) |
| 10 | Japan | 211 (3.6) | Journal of Urology | 53 (0.9) | Abolmaesumi P | 18 (0.3) |

NP: Number of Publications

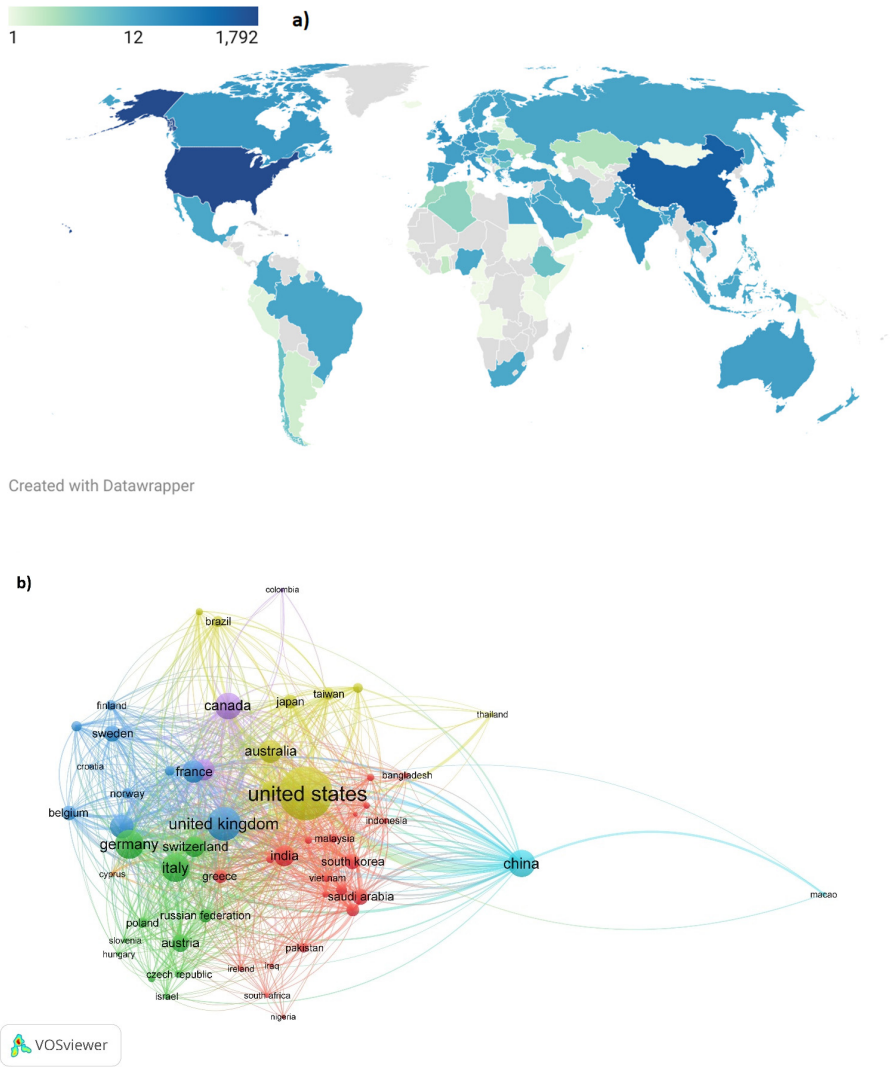


*Figure 2.* Global distribution (a) and collaboration network among countries (b) in urology and AI research. The node sizes correspond to the total link strength of each country, while the thickness of the connections indicates the link strength between countries, highlighting the leading role of the USA and notable contributions from other nations.

meaning they have cited more common articles—are typically represented in warmer colors like yellow and red. In contrast, journals with fewer connections are shown in cooler colors like blue or green. The proximity of journal names on the map signifies the degree of similarity or bibliographic connections between them. Journals that are closer together have cited more common articles or have been referenced by similar articles, while greater distances indicate weaker or fewer connections. Scientific Reports and PLOS One demonstrate a close relationship, reflecting their shared focus and frequent mutual citations. Similarly, the European Journal of Nuclear Medicine and Molecular Imaging is closely linked with Quantitative Imaging in Medicine and Surgery. At the same time, Computers in



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*Table 3.* The Top 10 Journals with the Strongest Bibliographic Coupling Relations in AI and Urology Studies

| No. | Journal | Cluster | Total link strength | Documents | Citations |
|---|---|---|---|---|---|
| 1 | Cancers | 3 | 33273 | 123 | 1234 |
| 2 | European Radiology | 3 | 22274 | 69 | 1936 |
| 3 | Scientific Reports | 1 | 22080 | 171 | 4581 |
| 4 | Diagnostics | 3 | 20911 | 83 | 1189 |
| 5 | Medical Physics | 5 | 17040 | 97 | 3047 |
| 6 | IEEE Access | 2 | 12805 | 66 | 1530 |
| 7 | Journal of Magnetic Resonance Imaging | 3 | 11486 | 32 | 807 |
| 8 | Computers in Biology and Medicine | 2 | 11155 | 68 | 1467 |
| 9 | Abdominal Radiology | 3 | 10018 | 45 | 732 |
| 10 | Medical Image Analysis | 2 | 8768 | 30 | 1578 |

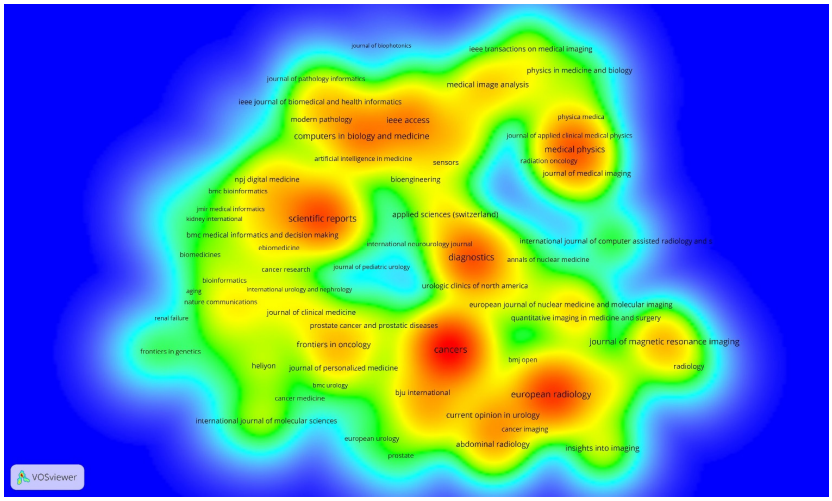


*Figure 3.* Rainbow density map of bibliographic coupling among journals in urology and AI. The map uses color variations to represent the strength of connections, with warmer colors indicating stronger bibliographic coupling based on shared references. The proximity of journal names reflects the degree of mutual citations, emphasizing notable relationships among leading journals such as Scientific Reports and PLOS One.

Biology and Medicine shows a strong connection with IEEE Access. Furthermore, Medical Physics and the Journal of Medical Imaging also exhibit significant bibliographic coupling. Additional details regarding these relationships are shown in Figure 3. This visualization further emphasizes the collaborative nature of research in this field and highlights the journals most relevant to urology and AI.

### *Influential Authors and Co-authorship Network Analysis*

Among the most prolific authors, Turkbey emerged as the leading contributor with 52 publications, representing 0.9% of the total publications in this field. Somani followed with 27 publications (0.4%), while Brooks and Madabhushi each contributed 25 publications (0.4%). The complete list of the top 10 authors and their respective publication counts is presented in Table 2. The co-authorship analysis revealed extensive collaboration among researchers. To focus on the most prolific authors, we set a minimum threshold of 10 documents per author. Out of 32,549 authors identified in the dataset, 102 met this criterion. The resulting co-authorship network comprised 6 distinct clusters, with the most significant connected component consisting of 27 authors, which is the primary focus of subsequent analyses. This network illustrates the various collaborative groups within the field, with notable interconnectedness among these core authors. The total link strength of the network was 554, indicating a substantial level of collaboration among the top contributors. Among the most collaborative authors, Turkbey emerged as the central figure with a total link strength of 132. Other key collaborators included Choyke and Pinto, both with a link strength of 74, followed closely by Wood, with a link strength of 70. Harmon and Xu also demonstrated strong collaborative ties, with a link strength of 62 and 59, respectively (Figure 4).

### *Co-occurrence Networks of Author Keywords*

To identify the most frequent author keywords in this field, a threshold of 10 occurrences was applied. Among 9,613 unique keywords, 274 met this criterion. Interestingly, the majority of these keywords are associated with the years 2019 to 2023, indicating significant growth and increased attention to these topics in recent years, as illustrated in the overlay visualization of term co-occurrence in Figure 5 a. The most frequently occurring keywords, based on total co-occurrences, were "machine learning" (n = 1331), "prostate cancer" (n = 955), "deep learning" (n =



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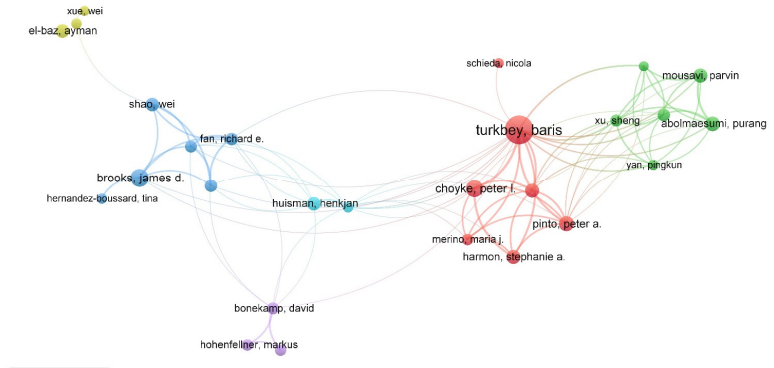


*Figure 4.* Co-Authorship Network in Urology and AI
The node sizes represent each author's overall collaborative reach, while the thickness of connections illustrates the strength of co-authorship links between authors. The network reveals distinct clusters of collaboration, highlighting key contributors and their interconnected relationships within the research field.

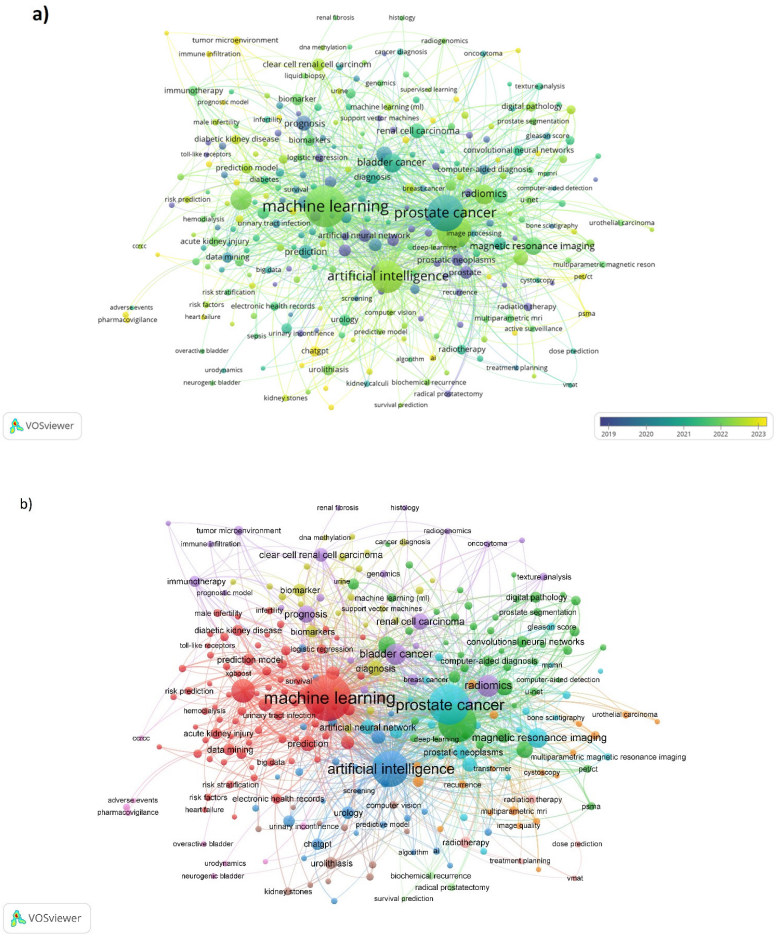


*Figure 5.* Overlay visualization (a) and Cluster analysis (b) of co-occurring author keywords in urology and AI. The node size indicates the number of publications associated with each keyword. In overlay visualization, the colors indicate the average publication year of each keyword, providing insights into recent trends and focal points in the research landscape.

838), "artificial intelligence" (n = 736), "chronic kidney disease" (n = 278), "radiomics" (n = 236), "bladder cancer" (n = 206), "magnetic resonance imaging" (n = 183), "classification" (n = 134), and "prognosis" (n = 132) (Ta-



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*Table 4.* Temporal Trends of Core Keywords in AI and Urology Research Across Three Distinct Periods

| No. | Keyword | 1971-2000 | 2001-2012 | 2013-2024 |
|---|---|---|---|---|
| 1 | Machine Learning | 0 | 0 | 1326 |
| 2 | Prostate Cancer | 14 | 53 | 891 |
| 3 | Deep Learning | 0 | 0 | 840 |
| 4 | Artificial Intelligence | 0 | 0 | 723 |
| 5 | Chronic Kidney Disease | 0 | 0 | 278 |
| 6 | Radiomics | 0 | 0 | 237 |
| 7 | Bladder Cancer | 0 | 11 | 191 |
| 8 | Magnetic Resonance Imaging | 0 | 0 | 181 |
| 9 | Classification | 0 | 0 | 122 |
| 10 | Prognosis | 8 | 11 | 113 |

ble 4). Cluster analysis revealed 11 distinct research domains, as shown in Figure 5 b. The first cluster, dominated by ML methodology, contained 76 keywords representing predictive modeling approaches for disease outcomes, with the most frequent terms being "machine learning" (n = 1331), "chronic kidney disease" (n = 278), and "prediction" (n = 102). This cluster emphasized predictive modeling, featuring high-frequency terms; for example, "feature selection" (n = 83), "neural network" (n = 74), and "random forest" (n = 71). The second cluster, comprising 46 keywords, focused on DL for medical image analysis, with the most frequent terms being "deep learning" (n = 838), "classification" (n = 134), "convolutional neural network" (n = 127), and "MRI" (n = 121). This cluster highlighted imaging analysis through commonly occurring terms like "segmentation" (n = 84) and "transfer learning" (n = 55).

The third cluster, consisting of 28 keywords, centered on AI applications in clinical practice, with "artificial intelligence" (n = 736) as the most frequent term. The cluster included emerging technologies and clinical applications, represented by frequent terms such as "urology" (n = 65), "ChatGPT" (n = 53), and "natural language processing" (n = 53), along with "kidney disease" (n = 29). The fourth cluster contained 25 keywords emphasizing diagnostic biomarkers and molecular analysis, with the most commonly occurring terms being "diagnosis" (n = 98) and "biomarker" (n = 65). The cluster emphasized molecular and analytical approaches through terms like "proteomics" (n = 22) and "metabolomics" (n = 20). The fifth cluster, with its 24 keywords, concentrated on radiomics applications in oncology, with the most frequent terms being "radiomics" (n = 236), "bladder cancer" (n = 206), and "prognosis" (n = 132). This cluster included specific cancer types, represented by high-frequency terms such as "renal cell carcinoma" (n = 122) and "clear cell renal cell carcinoma" (n = 82). The sixth cluster, comprising 24 keywords, focused on prostate cancer imaging and diagnostics, with the most commonly occurring terms being "prostate cancer" (n = 955) and "magnetic resonance imaging" (n = 183), along with specific diagnostic terms like "artificial neural network" (n = 83) and "prostatic neoplasms" (n = 78). Clusters seven through eleven showed increasing specialization: the seventh cluster (21 keywords) specialized in ultrasound imaging techniques with "ultrasound" (n = 41) as the primary term; the eighth cluster (13 keywords) focused on urolithiasis and kidney stone analysis with “urolithiasis” (n = 59) and kidney stones; the ninth cluster (9 keywords) concentrated on urinary conditions and drug safety; the tenth cluster (5 keywords) emphasized radiotherapy applications with "radiotherapy" (n = 47); and the eleventh cluster (3 keywords) focused on biochemical aspects of prostate cancer.

### *Temporal Author Keyword Trends Across Three Time Periods*

To investigate keyword trends over time, we segmented the study period into three distinct intervals: 1971-2000 (only 12 of these years included publications), 2001-2012, and 2013-2024. This temporal analysis allowed us to examine the evolution and significance of key research terms within each interval, highlighting shifts in focus and the development of new research themes (Figure 6). Additionally, we tracked the occurrence patterns of the overall top ten keywords across these intervals (Table 4), revealing their temporal progression and emergence. The initial period (1971-2000) represented foundational research, with sporadic publication patterns (Figure 6 a). Among the overall top ten keywords, only "prostate cancer" (14 occurrences) and "prognosis" (8 occurrences) were present during this period, complemented by "neural networks" (14 occurrences), reflecting early integration of computational methods in urological research. The intermediate period (2001-2012) showed substantial diversification, with "prostate cancer" emerging as the dominant theme (53 occurrences). This period marked the transition toward computational methodologies, evidenced by multiple variants of neural network terminology: "artificial neural network" (n = 22), "artificial neural networks" (n = 20), and "neural networks" (n = 20). Clinical keywords gained prominence, including "prostate" (n = 12) and "prostatic neoplasms" (n=11, Figure 6 b). Among the overall top 10 keywords, "bladder cancer" appeared with 11 occurrences, and "prognosis" maintained its presence with 11 occurrences (Table 4). The contemporary period (2013-2024) demonstrated exponential growth in AI applications (Figure 6 c). Among the overall top ten keywords, "machine learning" led with 1326 occurrences, followed by "prostate cancer" (n = 891), "deep learning" (n = 840), and "artificial intelligence" (n = 723). Clinical research expanded significantly, with "chronic kidney disease" (n = 278), "radiomics" (n = 237), "bladder cancer" (n = 191), "magnetic resonance imaging" (n = 181), "classification" (n = 122), and "prognosis" (n = 113) completing the keyword

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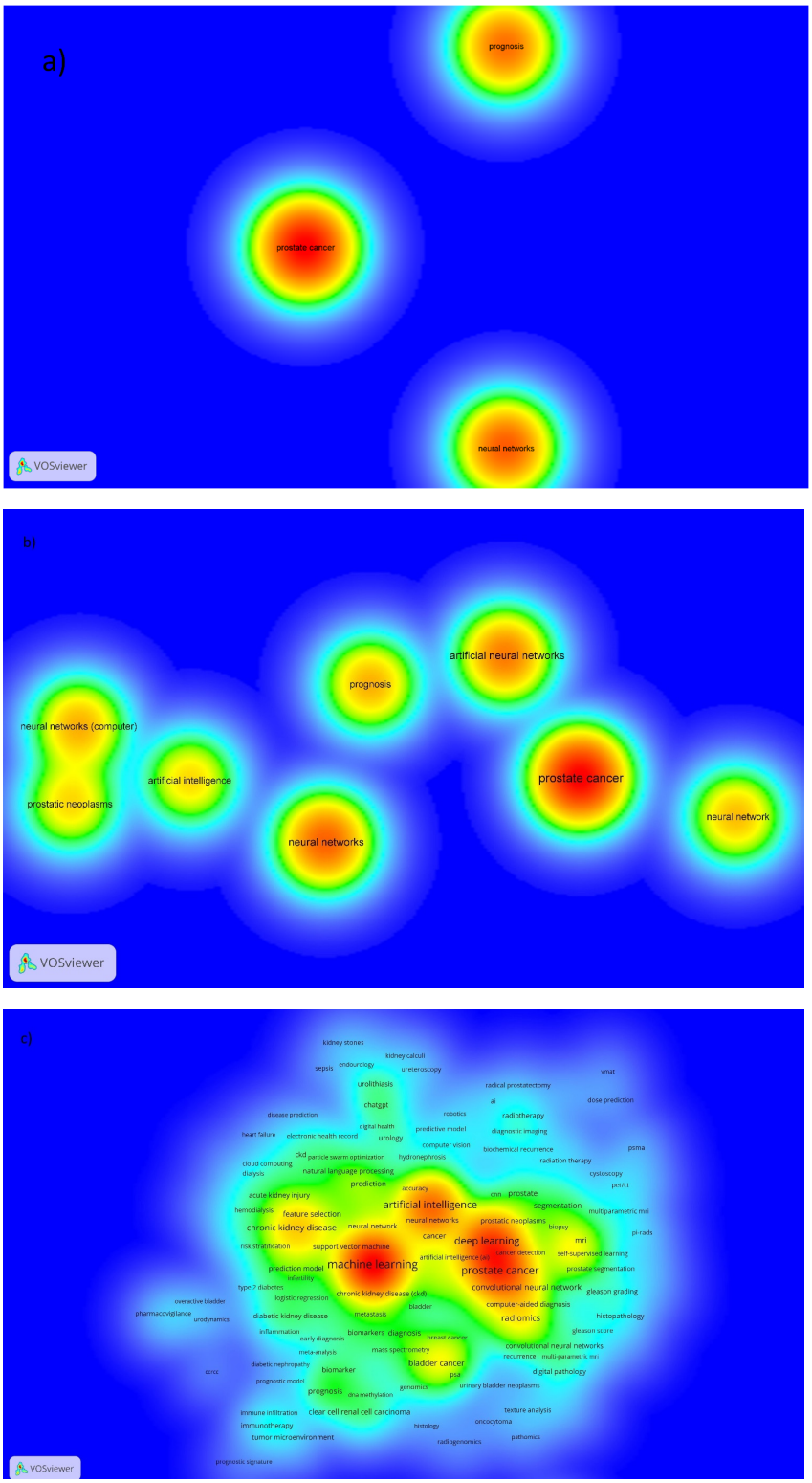


*Figure 6.* Item Density Visualization of Temporal Author Keyword Trends in Urology and AI. (a: Early Period (1971-2000), b: Intermediate Period (2001-2012), c: Contemporary Period (2013-2024)).

profile (Table 4). Interestingly, several new research domains emerged in this period, represented by keywords such as "pharmacovigilance," "FAERS," "urolithiasis," "ChatGPT," "VMAT," "Dose Prediction," and "robotics"



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(Figure 6 c).

### *Frequent Terms in Titles and Abstracts*

Our bibliometric analysis of article titles and abstracts reviewed 109,909 terms, identifying 1,758 with at least 20 occurrences. The most frequently occurring terms included "image" (1067 occurrences), "AUC" (856 occurrences), "chronic kidney disease" (801 occurrences), and "deep learning" (794 occurrences). Other notable terms were "age" (609 occurrences), "PCA" (567 occurrences), "CKD" (529 occurrences), "biomarker" (516 occurrences), "MRI" (487 occurrences), and "prognosis" (485 occurrences). We identified a total of five clusters, each representing a distinct area of focus within the broader topic, as depicted in Figure 7. Cluster 1 centers on chronic kidney disease (CKD), with key terms including "chronic kidney disease" (801 occurrences), "age" (n = 609), and "prediction model" (n = 330). This cluster highlights the relationship between kidney health and various predictive models used in clinical settings. Cluster 2 focuses on biomarkers and prognosis, featuring terms like "biomarker" (n = 516) and "gene" (n = 444). It emphasizes the role of biological markers in assessing disease progression and patient outcomes. Cluster 3 is dedicated to imaging techniques, prominently featuring "image" (n = 1067) and "deep learning" (n = 794). This cluster showcases advancements in imaging technologies and their applications in medical diagnostics. Cluster 4 relates to diagnostic metrics and includes terms such as "AUC" (n = 856) and "MRI" (n = 487). It focuses on the evaluation of diagnostic tools and their effectiveness in clinical practice. Finally, Cluster 5 covers literature reviews and advancements, containing terms "review" (n = 440) and "urology" (n = 157). This cluster reflects ongoing research trends and developments in the field, highlighting the importance of comprehensive reviews in synthesizing knowledge about AI applications in urology.

## Discussion

The bibliometric analysis demonstrates a rapid evolution of AI in urology, with publications increasing from 478 in 2020 to 1337 in 2024, reflecting accelerated AI integration and advancements in ML, DL architectures, and computational capabilities (16-19). The analysis revealed a high open access publication rate (63.9%) in AI and urology, significantly exceeding typical publication accessibility rates in other scientific domains (20) and reflecting a commitment to research dissemination and accelerated knowledge transfer (21).

The distribution across 21 subject areas, led by Medicine, Biochemistry, Genetics, Molecular Biology, and Computer Science, underscores AI's interdisciplinary role in urology. This integration is vital for developing clinically relevant AI solutions addressing real-world challenges (5, 22). Engineering and health professions further highlight the field's collaborative efforts. By 2024, 25,877 citations reflect the increasing research volume and impact, with the accelerating citation rate marking AI's shift from theory to practice, influencing clinical care and future research (23). This aligns with studies emphasizing AI's growing impact across medical specialties (24).

The analysis of highly cited publications reveals diverse applications and rapid advancements of AI in urology, with a focus on post-2010 studies emphasizing the field's contemporary relevance. Campanella et al's (2019) prominent study, with 279.6 citations per year, highlights AI's transformative role in histopathology (11). This aligns with the broader trend of AI implementation in diagnostic medicine, particularly in image-based specialties like pathology and radiology (25-29). The citation patterns of these influential works reveal 2 interconnected research streams: computational pathology (eg, Campanella et al) (11), and specific urological diagnostics (eg, Adam et al) (13), highlighting the field's focus on both specialized AI applications in pathology and broader diagnostic uses in urology.

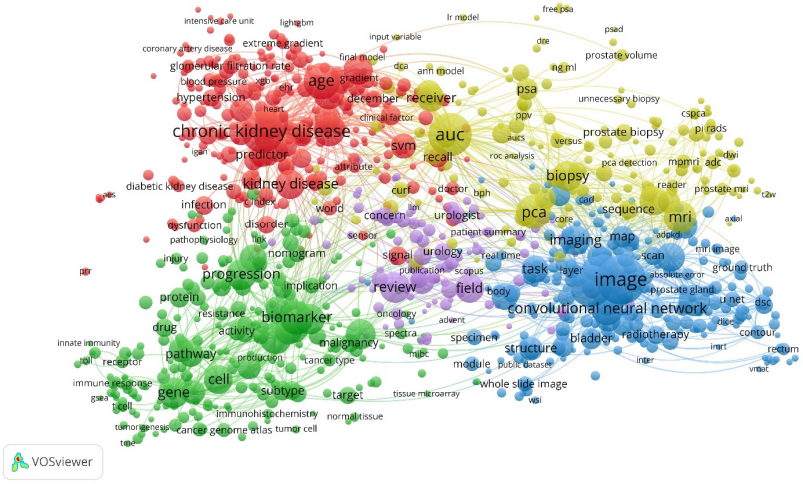


*Figure 7.* Cluster Analysis of Co-Occurrence of Terms in Titles and Abstracts. Node sizes indicate the number of publications associated with each term, reflecting the relative research volume within each theme.



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The geographical distribution of research highlights both opportunities and challenges in advancing AI in urology. The US (31.1%) and China (23.7%) lead in publication volume, reflecting significant investments in AI and medical research (30, 31). Together with India, these countries contribute 63% of publications, raising concerns about global equity in AI development for urological care. This concentration has profound implications for AI model generalizability, as algorithms trained predominantly on specific populations exhibit reduced accuracy when applied to underrepresented groups, potentially amplifying existing health disparities (32, 33). International collaboration, with a link strength of 5,594 across 57 countries, highlights growing global cooperation. The US acts as a central hub, fostering strong networks with Europe, particularly the UK and Germany, promoting knowledge exchange and technology transfer. However, minimal involvement from African nations reveals a gap in research distribution, raising concerns about the lack of representation of diverse patient populations critical for clinically robust AI systems (34). This geographic bias is particularly concerning as comprehensive analyses show that datasets from high-income countries dominate clinical AI research, with populations from low- and middle-income countries severely underrepresented (35). Such disparities may result in AI systems that fail to adequately serve diverse populations, potentially exacerbating healthcare inequalities (36).

To address these gaps, researchers advocate for more inclusive data collection practices and the implementation of fairness assessment frameworks to identify potential algorithmic biases before clinical deployment (32, 37, 38).

The notable engagement from Middle Eastern countries presents an opportunity for expanding the geographical and demographic scope of AI applications in urology.

The publication landscape of AI-urology research is widely distributed across journals, with Scientific Reports leading at just 2.9% of publications. This diversity reflects the field's broad relevance across scientific domains and its integration into both specialized and general research discourse (22, 39). The bibliographic coupling analysis highlights the intellectual structure of AI-urology (40, 41), with Cancers and European Radiology as central nodes in the knowledge network. The strong coupling between Scientific Reports and PLOS One reflects the open science movement's impact. The analysis also identifies distinct research sub-communities in specialized journals like European Journal of Nuclear Medicine and Molecular Imaging and Quantitative Imaging in Medicine and Surgery, showing the field's progression toward specialized technological applications.

The analysis of authorship patterns reveals a mix of concentrated expertise and diversity in AI-urology research. Turkbey stands out with 52 publications (0.9%) and a strong collaborative network (link strength: 132), marking key research hubs. Six author clusters, with the largest group of 27, reflect a structure that promotes both specialized knowledge and the exchange of diverse ideas (42).

The co-authorship network shows strong collaborations among authors like Choyke, Pinto, and Wood, forming stable research teams that drive consistent advancements. Additionally, independent research groups highlight multiple centers of innovation, promoting diverse approaches to common challenges (43, 44).

The alignment between productive authors and strong collaborations highlights AI-urology's reliance on team science and interdisciplinary expertise in urology, computer science, and data analysis (22, 45).

The keyword co-occurrence analysis highlights key patterns in the intellectual structure and development of AI in urology. The prominence of terms like "machine learning" and "deep learning" alongside "prostate cancer" shows the field's balance between technological innovation and clinical application (46, 47). The formation of eleven distinct research clusters indicates the field's maturation and specialization, particularly in areas like radiomics and precision diagnostics (48-51). The temporal analysis of keyword evolution reveals the field's transformation from basic neural networks (1971-2000) to advanced AI applications (2013-2024). The sharp increase in AI-related keywords after 2013 aligns with breakthroughs in DL and medical imaging (23). A key development is the emergence of specialized clusters, particularly the radiomics cluster, which is revolutionizing the analysis of imaging data in urological oncology (49, 52). Similarly, the emergence of natural language processing (NLP) and ChatGPT-related research indicates the rapid adoption of new AI in clinical applications (53-57). The emergence of ChatGPT as a prominent keyword in our analysis suggests growing clinical interest supported by preliminary validation studies demonstrating its potential utility in urological practice. Clinical studies have explored ChatGPT's applications in administrative tasks, showing capabilities in generating discharge summaries, clinical notes, and documentation that may reduce urologists' administrative burden (55, 56, 58). In patient care settings, ChatGPT-4 demonstrated comparable performance to physician groups in urological assessments and showed enhanced psychological support capabilities compared to ChatGPT-3.5 (59). For clinical decision support, ChatGPT showed reasonable safety for initial diagnostics in urolithiasis management, though limitations were noted in complex treatment planning compared to EAU guidelines (60). However, diagnostic imaging interpretation revealed initial limitations with accuracy rates of only 14% for CT and 28% for MRI cases, though this improved to 62% with organ guidance (61). Fine-tuning approaches have shown promise, with specialized training achieving 93.75% accuracy in renal cell carcinoma clinical questions (62). These findings suggest ChatGPT's potential as an auxiliary tool under expert supervision, particularly for administrative tasks, patient education, and initial clinical support, while emphasizing the need for human oversight in complex diagnostic scenarios (53, 63-66). Evaluations of GPT-4 in urolithiasis management showed reasonable safety for initial diagnostics but highlighted limitations in metaphylaxis and surgical planning compared to EAU guidelines (67). AI chatbots also demonstrated varying reliability in classifying dietary oxalate content, with ac-



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curacy ranging from 49% to 84% (68). However, ChatGPT showed over 95% accuracy in answering common urolithiasis-related questions, suggesting its potential for patient education (69). These findings indicate that while AI tools can support urological care, their implementation should be closely supervised and limited to validated applications.

An emerging research domain is the integration of pharmacovigilance and Food and Drug Administration (FDA) Adverse Event Reporting System (FAERS)-related studies, highlighting new approaches to drug safety monitoring in urology. AI and ML technologies, including NLP and DL, show promise in processing Individual Case Safety Reports (ICSRs) within FAERS. However, current systems require a "human-in-the-loop" approach for quality control, mainly due to challenges in data quality and the need for robust validation. The performance of these AI models is heavily influenced by the quality and quantity of available data, particularly in resource-limited settings (70, 71). AI integration has enabled early detection of adverse drug reactions and drug-induced toxicity, potentially improving patient safety (72). Nonetheless, the field faces challenges in developing standardized quality assurance methods and comprehensive training datasets (72, 73). Robotics is a key emerging domain in urology, with a shift from traditional non-AI robotic surgery to AI-enhanced platforms. ML algorithms have shown promise in assessing surgical skills through automated performance metrics (APMs) derived from instrument kinematic data, achieving up to 96% AUC in predicting surgeon proficiency in nerve-sparing robot-assisted radical prostatectomy (74) and predicting intraoperative complications like bleeding with models such as Random Forest achieving 74.5% accuracy in percutaneous nephrolithotomy (75) and Light Gradient Boosting demonstrating AUC of 0.933 across various urological procedures. These predictive models utilize key factors including operative time, D-dimer levels, and patient age to assess bleeding risk in real-time. (76). Our bibliometric analysis revealing robotics as an emerging keyword is supported by recent clinical implementations demonstrating AI integration with robotic platforms. Clinical studies show surgical intelligence platforms can objectively assess key surgical steps in robotic-assisted radical prostatectomy across multiple institutions, with analysis of 883 cases demonstrating measurable practice variability (77). Advanced robotic systems, including the Da Vinci SP and Senhance platforms, now offer enhanced capabilities such as tactile feedback and eye-tracking (78). At the same time, 3D reconstruction with augmented reality improves surgical precision by identifying anatomical relationships between tumors and surrounding structures (79). These developments validate our quantitative findings and demonstrate the field's progression toward AI-enhanced robotic surgery. AI-driven augmented reality systems have improved tumor localization during nerve-sparing procedures (80), and ML models can predict postoperative outcomes based on automated performance metrics (81). These advancements highlight the evolution of robotics integrating AI to enhance precision, decision support, and performance assessment. However, careful validation and integration of these intelligent systems are crucial for their widespread clinical use (82).

The integration of AI in volumetric modulated Arc radiotherapy (VMAT) treatment planning and dose prediction is transforming radiation therapy for prostate cancer. DL approaches have shown high accuracy in dose distribution predictions, with mean absolute errors of 1.9% for planning target volume and 1.3% for clinical target volume (83). This is a significant improvement over traditional methods, which take 5 to 30 minutes for optimization (84). Automated planning systems, such as those based on HD-U-net, have demonstrated clinical viability with average dose differences of 1.32% ± 1.35% for target structures and 2.08% ± 2.79% for organs at risk (85). These systems have excelled in optimizing dose-volume histograms for critical organs like the bladder and rectum, sometimes outperforming conventional plans (85). The implementation of ML algorithms in this field not only addresses efficiency challenges but also enhances treatment plan quality by enabling more extensive exploration of planning options (84, 86). Recent feasibility studies have further validated these approaches, with some models achieving Dice similarity coefficients of 0.91 when comparing predicted versus actual isodose volumes (86, 87).

The analysis of frequent terms in titles and abstracts highlights a focus on quantifiable outcomes and clinical validation, with terms like "AUC" and "biomarker" suggesting rigorous AI validation in clinical settings (88-92). Five clusters align with key clinical priorities: CKD management, biomarker discovery, imaging analysis, diagnostic metrics, and knowledge synthesis (93). The prominence of imaging terms (1,067 occurrences for "image") underscores computer vision's central role in urological AI research (94, 95). This trend, combined with the high frequency of diagnostic and prognostic terms, suggests that the field is moving toward more integrated AI solutions that combine multiple data modalities for improved clinical decision-making (23, 96-99).

Future directions in urology show promising advancements. The integration of AI is progressing towards personalized medicine, combining genomic, imaging, and clinical data to form comprehensive patient profiles. NLP and large language models (LLMs) show promise for patient education but need refinement for clinical support. AI-enhanced robotic surgery aids in skill assessment and complication prediction, while emerging pharmacovigilance applications could improve outcomes. However, these innovations require ethical consideration and validation. Future research should focus on creating clinically robust AI solutions that represent diverse patient populations and encourage international collaboration for standardized implementation in clinical practice. This study has limitations, including its focus on English-language publications and reliance on the Scopus database, which may miss studies from other sources. Rapid AI advancements, especially in NLP and LLMs, may also not be fully captured due to publication delays. Future research could address these gaps by including multiple databases, lan-

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guages, and unpublished studies (e.g., preprints).

## Conclusion

The bibliometric analysis of 5755 publications (1971–2024) with 25,877 citations and a 63.9% open access rate underscores AI's transformative role in urology, driven by interdisciplinary collaboration and open access. Research clusters in radiomics, diagnostic imaging, and biomarker discovery address key clinical challenges, while collaboration patterns underscore the success of team-based AI research in healthcare solutions. As AI continues to integrate into clinical workflows, ongoing research must address ethical, technical, and practical considerations, particularly around patient safety and the equitable representation of diverse populations. The field's next phase may involve expanding applications beyond high-resource settings and developing standards for evaluating AI systems in clinical practice. Future studies should prioritize standardized protocols for AI validation in urology to ensure clinical reliability and facilitate consistent evaluation across diverse clinical settings and populations. Addressing these challenges and continuing to foster international collaboration will be essential in realizing AI's full potential in enhancing patient care and clinical outcomes in urology. These insights can inform research priorities, allocation of resources, and collaborative endeavors, all of which, in due course, would improve our understanding and management of urological conditions.

### *Authors' Contributions*

KH and SBK conceptualized the study, designed the research methodology, and led the data analysis and interpretation. GM contributed to the systematic literature search and data synthesis. HAK provided methodological expertise and participated in data validation. AF contributed to the theoretical framework development and manuscript drafting. HA performed the systematic literature search and conducted data analysis. MRF provided statistical guidance and contributed to quality assessment of included studies. FS participated in data extraction and verification processes. HD provided overall supervision throughout the research process, offered critical academic guidance, and conducted comprehensive review of the manuscript. All authors contributed to manuscript revision and approved the final version for submission.

### *Ethical Considerations*

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

### *Acknowledgment*

Not applicable.

### *Conflict of Interests*

The authors declare that they have no competing interests.

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*Appendix.* Comprehensive MeSH Terms, Keywords and Related Variations and Search Strategies Used in Scopus Database for Urological Literature

1)

TITLE-ABS ( "Computer vision" ) OR TITLE-ABS ( "Image recognition" ) OR TITLE-ABS ( "Artificial intelligence" ) OR TITLE-ABS ( "Natural language processing" ) OR TITLE-ABS ( "Natural language understanding" ) OR TITLE-ABS ( "Natural language interpretation" ) OR TITLE-ABS ( "Deep learning" ) OR TITLE-ABS ( "Machine learning" ) OR TITLE-ABS ( "Predictive analytics" ) OR TITLE-ABS ( "Pattern recognition" ) OR TITLE-ABS ( "Reinforcement learning" ) OR TITLE-ABS ( "Unsupervised learning" ) OR TITLE-ABS ( "Supervised learning" ) OR TITLE-ABS ( "AI-driven diagnosis" ) OR TITLE-ABS ( "AI driven diagnosis" ) OR TITLE-ABS ( "AI-powered" ) OR TITLE-ABS ( "AI powered" ) OR TITLE-ABS ( "AI-assisted" ) OR TITLE-ABS ( "AI assisted" ) OR TITLE-ABS ( "Neural network*" ) OR TITLE-ABS ( "Computational intelligence" ) OR TITLE-ABS ( "Large language model*" ) OR TITLE-ABS ( "Generative AI" ) OR TITLE-ABS ( "Federated learning" ) OR TITLE-ABS ( "Transfer learning" ) OR TITLE-ABS ( "Knowledge representation" ) OR TITLE-ABS ( "Robotic Surgery" ) OR TITLE-ABS ( "AI-driven Robotic Process Automation" ) OR TITLE-ABS ( "AI driven Robotic Process Automation" ) OR TITLE-ABS ( "AI-driven RPA" ) OR TITLE-ABS ( "AI driven RPA" )

2)

TITLE-ABS ( Urology ) OR TITLE-ABS ( "Reproductive Tract Infection*" ) OR TITLE-ABS ( "Genital Tract Infection*" ) OR TITLE-ABS ( "Spermatic Cord Torsion*" ) OR TITLE-ABS ( "Testicular Torsion*" ) OR TITLE-ABS ( "Torsion of Testicular Cord" ) OR TITLE-ABS ( spermatocel* ) OR TITLE-ABS ( "Epididymal Cyst*" ) OR TITLE-ABS ( "Testicular Disease*" ) OR TITLE-ABS ( cryptorchidism ) OR TITLE-ABS ( cryptorchism ) OR TITLE-ABS ( "Undescended Testicl*" ) OR TITLE-ABS ( "Bilateral Cryptorchidism" ) OR TITLE-ABS ( "Unilateral Cryptorchidism" ) OR TITLE-ABS ( "Abdominal Cryptorchidism" ) OR TITLE-ABS ( "Inguinal Cryptorchidism" ) OR TITLE-ABS ( orchitis ) OR TITLE-ABS ( "Testicular Hydrocel*" ) OR TITLE-ABS ( "Scrotal Hydrocel*" ) OR TITLE-ABS ( "Vaginal Hydrocel*" ) OR TITLE-ABS ( "Male Genital Tuberculos*" ) OR TITLE-ABS ( "Varicocel*" ) OR TITLE-ABS ( globozoospermia ) OR TITLE-ABS ( "Penile Disease*" ) OR TITLE-ABS ( "Penis Disease*" ) OR TITLE-ABS ( balanitis ) OR TITLE-ABS ( "Balanitis Xerotica Obliterans" ) OR TITLE-ABS ( "Kraurosis Penis" ) OR TITLE-ABS ( "Penile Induration" ) OR TITLE-ABS ( "Fibrous Cavernitis" ) OR TITLE-ABS ( "Peyronie Disease" ) OR TITLE-ABS ( "Peyronie's Disease" ) OR TITLE-ABS ( "Peyronies Disease" ) OR TITLE-ABS ( "Plastic Induration of the Penis" ) OR TITLE-ABS ( "Penile Fibromatosis" ) OR TITLE-ABS ( phimosis ) OR TITLE-ABS ( paraphimosis ) OR TITLE-ABS ( priapism ) OR TITLE-ABS ( priapisms ) OR TITLE-ABS ( "Prostatic Disease*" ) OR TITLE-ABS ( "Prostatic Hyperplasia" ) OR TITLE-ABS ( "Prostatic Adenoma" ) OR TITLE-ABS ( "Prostatic Hypertrophy" ) OR TITLE-ABS ( "Prostatic Hypertrophies" ) OR TITLE-ABS ( "Benign Prostatic Hyperplasia" ) OR TITLE-ABS ( "Benign Prostatic Hypertrophy" ) OR TITLE-ABS ( prostatitis ) OR TITLE-ABS ( "Acute Bacterial Prostatitis" ) OR TITLE-ABS ( "Chronic Bacterial Prostatitis" ) OR TITLE-ABS ( "Chronic Prostatitis with Chronic Pelvic Pain Syndrome" ) OR TITLE-ABS ( "Asymptomatic Inflammatory Prostatitis" ) OR TITLE-ABS ( "Fournier's Gangrene" ) OR TITLE-ABS ( "Fourniers Gangrene" ) OR TITLE-ABS ( hematocele ) OR TITLE-ABS ( hematoceles ) OR TITLE-ABS ( "Testicular Hematocele*" ) OR TITLE-ABS ( "Scrotal Hematocele*" ) OR TITLE-ABS ( hemospermia ) OR TITLE-ABS ( hematospermia ) OR TITLE-ABS ( "Herpes Genitalis" ) OR TITLE-ABS ( "Genital Herpes Simplex" ) OR TITLE-ABS ( "Genital Herpes" ) OR TITLE-ABS ( "Herpes Simplex Virus Genital Infection" ) OR TITLE-ABS ( "Male Infertility" ) OR TITLE-ABS ( "Male Sterility" ) OR TITLE-ABS ( "Male Subfertility" ) OR TITLE-ABS ( "Male Sub-Fertility" ) OR TITLE-ABS ( aspermia ) OR TITLE-ABS ( asthenozoospermia ) OR TITLE-ABS ( "Astheno Teratozoospermia" ) OR TITLE-ABS ( asthenoteratozoospermia ) OR TITLE-ABS ( azoospermia ) OR TITLE-ABS ( oligospermia ) OR TITLE-ABS ( "Sertoli Cell-Only Syndrome" ) OR TITLE-ABS ( "Sertoli Cell Only Syndrome" ) OR TITLE-ABS ( "Germinal Cell Aplasia" ) OR TITLE-ABS ( "Del Castillo Syndrome" ) OR TITLE-ABS ( teratozoospermia ) OR TITLE-ABS ( teratospermia ) OR TITLE-ABS ( "Abnormal Spermatozoa" ) OR TITLE-ABS ( "Cancer of Urinary Tract" ) OR TITLE-ABS ( "Urinary Tract Cancer*" ) OR TITLE-ABS ( "Urologic Cancer*" ) OR TITLE-ABS ( "Cancer of the Urinary Tract" ) OR TITLE-ABS ( "Urological Cancer*" ) OR TITLE-ABS ( "Transmissible Venereal Tumor*" ) OR TITLE-ABS ( "Veterinary Venereal Tumor*" ) OR TITLE-ABS ( dyspareunia ) OR TITLE-ABS ( "Ejaculatory Dysfunction*" ) OR TITLE-ABS ( "Ejaculation Dysfunction*" ) OR TITLE-ABS ( anejaculation ) OR TITLE-ABS ( "Delayed Ejaculation" ) OR TITLE-ABS ( "Ejaculatory Incompetence" ) OR TITLE-ABS ( "Premature Ejaculation*" ) OR TITLE-ABS ( "Ejaculatio Praecox" ) OR TITLE-ABS ( "Retrograde Ejaculation*" ) OR TITLE-ABS ( epididymitis ) OR TITLE-ABS ( "Erectile Dysfunction" ) OR TITLE-ABS ( impotence ) OR TITLE-ABS ( "Male Impotence" ) OR TITLE-ABS ( "Male Sexual Impotence" ) OR TITLE-ABS ( "Vasculogenic Impotence" ) OR TITLE-ABS ( "Arteriogenic Impotence" ) OR TITLE-ABS ( "Venogenic Impotence" ) OR TITLE-ABS ( "Penile Venous Leakage" ) OR TITLE-ABS ( "Fournier Gangrene" ) OR TITLE-ABS ( "Fournier Disease" ) OR TITLE-ABS ( "Fournier's Disease" ) OR TITLE-ABS ( "Fourniers Disease" ) OR TITLE-ABS ( "Androgen-Insensitive Prostatic Cancer*" ) OR TITLE-ABS ( "Androgen Insensitive Prostatic Cancer*" ) OR TITLE-ABS ( "Androgen-Resistant Prostatic Cancer*" ) OR TITLE-ABS ( "Androgen Resistant Prostatic Cancer*" ) OR TITLE-ABS ( "Castration Resistant Prostatic Cancer*" ) OR TITLE-ABS ( "Hormone Refractory Prostatic Cancer*" ) OR TITLE-ABS ( "Androgen-Independent Prostatic Cancer*" ) OR TITLE-ABS ( "Androgen Independent Prostatic Cancer*" ) OR TITLE-ABS ( "Testicular Neoplasm*" ) OR TITLE-ABS ( "Testicular Tumor*" ) OR TITLE-ABS ( "Testis Neoplasm*" ) OR TITLE-ABS ( "Tumor of Rete Testis" ) OR TITLE-ABS ( "Rete Testis Tumor*" ) OR TITLE-ABS ( "Cancer of Testis" ) OR TITLE-ABS ( "Testicular Cancer*" ) OR TITLE-ABS ( "Testis Cancer*" ) OR TITLE-ABS ( "Cancer of the Testis" ) OR TITLE-ABS ( "Sertoli-Leydig Cell Tumor*" ) OR TITLE-ABS ( "Sertoli Leydig Cell Tumor*" ) OR TITLE-ABS ( androblastoma ) OR TITLE-ABS ( androblastomas ) OR TITLE-ABS ( arrhenoblastoma ) OR TITLE-ABS ( arrhenoblastomas ) OR TITLE-ABS ( "Leydig Cell Tumor*" ) OR TITLE-ABS ( "Interstitial Cell Tumor*" ) OR TITLE-ABS ( "Sertoli Cell Tumor*" ) OR TITLE-ABS ( "Urologic Neoplasm*" ) OR TITLE-ABS ( "Urological Neoplasm*" ) OR TITLE-ABS ( "Urinary Tract Neoplasm*" ) OR TITLE-ABS ( "Genitourinary Neoplasm*" ) OR TITLE-ABS ( "Genito-urinary Neoplasm*" ) OR TITLE-ABS ( "Genitourinary Cancer*" ) OR TITLE-ABS ( "Urogenital Cancer*" ) OR TITLE-ABS ( "Genito-urinary Cancer*" ) OR TITLE-ABS ( "Genito urinary Cancer*" ) OR TITLE-ABS ( "Male Genital Neoplasm*" ) OR TITLE-ABS ( "Penile Neoplasm*" ) OR TITLE-ABS ( "Penis Neoplasm*" ) OR TITLE-ABS ( "Cancer of Penis" ) OR TITLE-ABS ( "Penile Cancer*" ) OR TITLE-ABS ( "Cancer of the Penis" ) OR TITLE-ABS ( "Penis Cancer*" ) OR TITLE-ABS ( "Prostatic Neoplasm*" ) OR TITLE-ABS ( "Prostate Neoplasm*" ) OR TITLE-ABS ( "Prostate Cancer*" ) OR TITLE-ABS ( "Cancer of Prostate" ) OR TITLE-ABS ( "Cancer of the Prostate" ) OR TITLE-ABS ( "Prostatic Cancer*" ) OR TITLE-ABS ( "Castration-Resistant Prostatic Neoplasm*" ) OR TITLE-ABS ( "Androgen-Independent Prostatic Neoplasm*" ) OR TITLE-ABS ( "Androgen Independent Prostatic Neoplasm*" ) OR TITLE-ABS ( "Androgen-Insensitive Prostatic Neoplasm*" ) OR TITLE-ABS ( "Androgen Insensitive Prostatic Neoplasm*" ) OR TITLE-ABS ( "Androgen-Resistant Prostatic Neoplasm*" ) OR TITLE-ABS ( "Androgen Resistant Prostatic Neoplasm*" ) OR TITLE-ABS ( "Castration Resistant Prostatic Neoplasm*" ) OR TITLE-ABS ( "Hormone Refractory Prostatic Neoplasm*" ) OR TITLE-ABS ( "Castration-Resistant Prostatic Cancer*" ) ) OR TITLE-ABS ( "Kidney Fusion*" ) OR TITLE-ABS ( "Lobulation of Kidney" ) OR TITLE-ABS ( "Kidney Lobulation*" ) OR TITLE-ABS ( "Congenital Fusion of Kidneys" ) OR TITLE-ABS ( "Congenital Lobulation of Kidneys" ) OR TITLE-ABS ( "Renal Fusion*" ) OR TITLE-ABS ( "Horseshoe Kidney*" ) OR TITLE-ABS ( "Cake Kidney" ) OR TITLE-ABS ( "Cake Kidneys" ) OR TITLE-ABS ( "Pelvic Cake Kidney" ) OR TITLE-ABS ( "Pelvic Cake Kidneys" ) OR TITLE-ABS ( "Crossed Fused Ectopia" ) OR TITLE-ABS ( "Crossed Fused Ectopias" ) OR TITLE-ABS ( "Crossed Fused Ectopia of Kidneys" ) OR TITLE-ABS ( hypospadias ) OR TITLE-ABS ( hypospadia ) OR TITLE-ABS ( "Retrocaval Ureter" ) OR TITLE-ABS ( "Circumcaval Ureter" ) OR TITLE-ABS ( "Solitary Kidney" ) OR TITLE-ABS ( "Single Kidney" )

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OR TITLE-ABS ( "Single Kidneys" ) OR TITLE-ABS ( "Single Functioning Kidney" ) OR TITLE-ABS ( "Single Functioning Kidneys" ) OR TITLE-ABS ( "Unilateral Renal Agenesis" ) OR TITLE-ABS ( "Solitary Functioning Kidney" ) OR TITLE-ABS ( "Unilateral Renal Hypoplasia" ) OR TITLE-ABS ( "Urinary Fistula" ) OR TITLE-ABS ( "Urinary Fistulas" ) OR TITLE-ABS ( "Urogenital Neoplasm*" ) OR TITLE-ABS ( "Monosomy X" ) OR TITLE-ABS ( "Ovotesticular Disorders of Sex Development" ) OR TITLE-ABS ( "Ovotesticular DSD" ) OR TITLE-ABS ( "Ovotesticular DSDs" ) OR TITLE-ABS ( "Ovotesticular Disorder of Sex Development" ) OR TITLE-ABS ( "True Hermaphroditism*" ) OR TITLE-ABS ( "Familial True Hermaphroditism*" ) OR TITLE-ABS ( "Familial XX True Hermaphroditism" ) OR TITLE-ABS ( "Sex Chromosome Disorders of Sex Development" ) OR TITLE-ABS ( "Sex Chromosome DSD" ) OR TITLE-ABS ( "Sex Chromosome DSDs" ) OR TITLE-ABS ( "Freemartinism" ) OR TITLE-ABS ( "Klinefelter Syndrome*" ) OR TITLE-ABS ( "Klinefelter's Syndrome" ) OR TITLE-ABS ( "Klinefelters Syndrome" ) OR TITLE-ABS ( "XXY Syndrome*" ) OR TITLE-ABS ( "XXY Trisomy" ) OR TITLE-ABS ( "XXY Trisomies" ) OR TITLE-ABS ( "Xxyy Syndrome*" ) OR TITLE-ABS ( "XXXY Male*" ) OR TITLE-ABS ( "Fraser Syndrome" ) OR TITLE-ABS ( "Cryptophthalmos-Syndactyly Syndrome*" ) OR TITLE-ABS ( "Cryptophthalmos Syndactyly Syndrome" ) OR TITLE-ABS ( "Cryptophthalmos with Other Malformation*" ) OR TITLE-ABS ( "Fused Kidney" ) OR TITLE-ABS ( "Fused Kidneys" ) OR TITLE-ABS ( "Lobulated Kidney" ) OR TITLE-ABS ( "Lobulated Kidneys" ) OR TITLE-ABS ( "Fusion of Kidney" ) ) ) OR ( ( TITLE-ABS ( "Kallmann Syndrome" ) OR TITLE-ABS ( "Anosmic Hypogonadism*" ) OR TITLE-ABS ( "Anosmic Idiopathic Hypogonadotropic Hypogonadism" ) OR TITLE-ABS ( "Dysplasia Olfactogenitalis of De Morsier" ) OR TITLE-ABS ( "Hypogonadotropic Hypogonadism and Anosmia" ) OR TITLE-ABS ( "Hypogonadotropic Hypogonadism-Anosmia Syndrome" ) OR TITLE-ABS ( "Kallmann's Syndrome" ) OR TITLE-ABS ( "Kallmanns Syndrome" ) OR TITLE-ABS ( "Kallmann Syndrome 1" ) OR TITLE-ABS ( "Kallmann Syndrome 2" ) OR TITLE-ABS ( "Autosomal Dominant Form of Kallmann Syndrome" ) OR TITLE-ABS ( "Kallmann Syndrome 3" ) OR TITLE-ABS ( "Autosomal Recessive Form of Kallmann Syndrome" ) OR TITLE-ABS ( "Gonadal Dysgenesis" ) OR TITLE-ABS ( "Gonadal Agenesis" ) OR TITLE-ABS ( gonadoblastoma ) OR TITLE-ABS ( "Mixed Gonadal Dysgenesis" ) OR TITLE-ABS ( "Sexual Infantilism" ) OR TITLE-ABS ( "Genital Infantilism" ) OR TITLE-ABS ( "Turner Syndrome" ) OR TITLE-ABS ( "Turner's Syndrome" ) OR TITLE-ABS ( "Turners Syndrome" ) OR TITLE-ABS ( "Ullrich-Turner Syndrome" ) OR TITLE-ABS ( "Ullrich Turner Syndrome" ) OR TITLE-ABS ( "Bonnevie-Ullrich Syndrome" ) OR TITLE-ABS ( "Bonnevie Ullrich Syndrome" ) OR TITLE-ABS ( "Status Bonnevie-Ullrich" ) OR TITLE-ABS ( "Status Bonnevie Ullrich" ) OR TITLE-ABS ( "XO Gonadal Dysgenesis" ) OR TITLE-ABS ( "Male Pseudohermaphroditism*" ) OR TITLE-ABS ( "Androgen-Insensitivity Syndrome*" ) OR TITLE-ABS ( "Androgen Insensitivity Syndrome*" ) OR TITLE-ABS ( "Androgen Resistance Syndrome*" ) OR TITLE-ABS ( "Male Pseudohermaphroditism Due to Androgen Insensitivity" ) OR TITLE-ABS ( "Testicular Feminization*" ) OR TITLE-ABS ( "Complete Androgen-Insensitivity Syndrome*" ) OR TITLE-ABS ( "Testicular Feminization Syndrome*" ) OR TITLE-ABS ( "Reifenstein Syndrome" ) OR TITLE-ABS ( "Partial Androgen Insensitivities" ) OR TITLE-ABS ( "Partial Androgen Insensitivity" ) OR TITLE-ABS ( "Partial Androgen-Insensitivity Syndrome*" ) OR TITLE-ABS ( "Partial Androgen Insensitivity Syndrome*" ) OR TITLE-ABS ( "Reifenstein's Syndrome" ) OR TITLE-ABS ( "Reifensteins Syndrome" ) OR TITLE-ABS ( "Androgen Receptor Deficiency" ) OR TITLE-ABS ( "Androgen Receptor Deficiencies" ) OR TITLE-ABS ( "Dihydrotestosterone Receptor Deficiency" ) OR TITLE-ABS ( "Dihydrotestosterone Receptor Deficiencies" ) OR TITLE-ABS ( "AR Deficiency" ) OR TITLE-ABS ( "AR Deficiencies" ) OR TITLE-ABS ( "DHTR Deficiency" ) OR TITLE-ABS ( 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TITLE-ABS ( oliguria ) OR TITLE-ABS ( "Urinary Incontinence" ) OR TITLE-ABS ( "Urinary Stress Incontinence" ) OR TITLE-ABS ( "Urge Incontinence" ) OR TITLE-ABS ( "Urinary Reflex Incontinence" ) OR TITLE-ABS ( "Urinary Urge Incontinence" ) OR TITLE-ABS ( "Urinary Retention" ) OR TITLE-ABS ( urolithiasis ) OR TITLE-ABS ( "Urinary Lithiasis" ) OR TITLE-ABS ( "Female Urogenital Disease*" ) OR TITLE-ABS ( "Female Genitourinary Disease*" ) OR TITLE-ABS ( "Urogenital Tuberculosis" ) OR TITLE-ABS ( "Female Genital Tuberculosis" ) OR TITLE-ABS ( "Male Genital Tuberculosis" ) OR TITLE-ABS ( "Urogenital Abnormalities" ) OR TITLE-ABS ( "Urogenital Abnormality" ) OR TITLE-ABS ( "Genitourinary Abnormalities" ) OR TITLE-ABS ( "Bladder Neurogenesis" ) OR TITLE-ABS ( "Atonic Neurogenic Bladder" ) OR TITLE-ABS ( "Spastic Neurogenic Bladder" ) OR TITLE-ABS ( "Uninhibited Neurogenic Bladder" ) OR TITLE-ABS ( "Overactive Bladder" ) OR TITLE-ABS ( "Overactive Urinary Bladder" ) OR TITLE-ABS ( "Overactive Detrusor" ) OR TITLE-ABS ( "Overactive Detrusor Function" ) OR TITLE-ABS ( "Underactive Bladder*" ) OR TITLE-ABS ( "Underactive Urinary Bladder*" ) OR TITLE-ABS ( "Detrusor Underactivity" ) OR TITLE-ABS ( "Underactive Detrusor*" ) OR TITLE-ABS ( "Underactive Detrusor Function*" ) OR TITLE-ABS ( "Hypotonic Bladder*" ) OR TITLE-ABS ( "Vesico-Ureteral Reflux" ) OR TITLE-ABS ( "Vesico Ureteral Reflux" ) OR TITLE-ABS ( "Vesicoureteral Reflux" ) OR TITLE-ABS ( "Vesicoureteral Reflux 1" ) OR TITLE-ABS ( "Vesicoureteral Reflux Grade1" ) OR TITLE-ABS ( "Vesicoureteral Reflux1" ) OR TITLE-ABS ( "Vesicoureteral Reflux1s" ) OR TITLE-ABS ( "Primary Vesicoureteral Reflux" ) OR TITLE-ABS ( "Secondary Vesicoureteral Reflux" ) OR TITLE-ABS ( "Urinary Tract Infection*" ) OR TITLE-ABS ( bacteriuria ) OR TITLE-ABS ( pyuria ) OR TITLE-ABS ( "Schistosomiasis haematobia" ) OR TITLE-ABS ( "Schistosoma haematobia Infection*" ) OR TITLE-ABS ( "Schistosomiasis haematobium" ) OR TITLE-ABS ( "Urinary Bladder Stone*" ) OR TITLE-ABS ( "Vesical Calculi" ) OR TITLE-ABS ( "Vesical Calculus" ) OR TITLE-ABS ( "Urinary Bladder Fistula*" ) OR TITLE-ABS ( "Vesical Fistula*" ) OR TITLE-ABS ( "Vesicovaginal Fistula*" ) OR TITLE-ABS ( "Vesico-Vaginal Fistula*" ) OR TITLE-ABS ( "Vesico Vaginal Fistula*" ) OR TITLE-ABS ( "Urinary Bladder Neoplasm*" ) OR TITLE-ABS ( "Bladder Neoplasm*" ) OR TITLE-ABS ( "Bladder Tumor*" ) OR TITLE-ABS ( "Urinary Bladder Cancer*" ) OR TITLE-ABS ( "Bladder Cancer*" ) OR TITLE-ABS ( "Cancer of Bladder" ) OR TITLE-ABS ( "Cancer of the Bladder" ) OR TITLE-ABS ( "Malignant Tumor of Urinary Bladder" ) OR TITLE-ABS ( "Non-Muscle Invasive Bladder Neoplasm*" ) OR TITLE-ABS ( "Non Muscle Invasive Bladder Neoplasm*" ) OR TITLE-ABS ( "Non-Muscle Invasive Bladder Cancer*" ) OR TITLE-ABS ( nmibc ) OR TITLE-ABS ( "Non-Muscle-Invasive Bladder Cancer*" ) OR TITLE-ABS ( "Neurogenic Urinary Bladder" ) OR TITLE-ABS ( "Neurogenic Bladder" ) OR TITLE-ABS ( "Neurogenic Bladder Disorder*" ) OR 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the Bladder" ) OR TITLE-ABS ( "Urinary Bladder Exstrophy" ) OR TITLE-ABS ( "Urinary Bladder Exstrophies" ) OR TITLE-ABS ( "Exstrophy of Bladder" ) OR TITLE-ABS ( cystitis ) OR TITLE-ABS ( "Hemorrhagic Cystitis" ) OR TITLE-ABS ( "Interstitial Cystitis" ) OR TITLE-ABS ( "Chronic Interstitial Cystitis" ) OR TITLE-ABS ( "Painful Bladder Syndrome" ) OR TITLE-ABS ( "Bladder Pain Syndrome*" ) OR TITLE-ABS ( cystocele ) OR TITLE-ABS ( "Fallen Urinary Bladder" ) OR TITLE-ABS ( "Urinary Bladder Prolapse" ) OR TITLE-ABS ( "Urinary Bladder Calculi" ) OR TITLE-ABS ( "Urinary Bladder Calculus" ) OR TITLE-ABS ( "Bladder Calculi" ) OR TITLE-ABS ( "Bladder Calculus" ) OR TITLE-ABS ( "Bladder Stone*" ) OR TITLE-ABS ( "Calculi of Urinary Bladder" ) OR TITLE-ABS ( cystolith* ) OR TITLE-ABS ( "WAGR Complex" ) OR TITLE-ABS ( "WAGR Contiguous Gene Syndrome" ) OR TITLE-ABS ( "Wilms Tumor-Aniridia-Gonadoblastoma-Mental Retardation Syndrome" ) OR TITLE-ABS ( "Renal Tuberculosis" ) OR TITLE-ABS ( "Ureteral 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Adenocarcinoma*" ) OR TITLE-ABS ( "Adenocarcinoma of Kidney" ) OR TITLE-ABS ( "Hypernephroid Carcinoma*" ) OR TITLE-ABS ( "Grawitz Tumor*" ) OR TITLE-ABS ( hypernephroma ) OR TITLE-ABS ( "Clear Cell Renal Carcinoma" ) OR TITLE-ABS ( "Papillary Renal Cell Carcinoma" ) OR TITLE-ABS ( "Chromophil Renal Cell Carcinoma" ) OR TITLE-ABS ( "Chromophobe Renal Cell Carcinoma" ) OR TITLE-ABS ( "Collecting Duct Carcinoma*" ) OR TITLE-ABS ( "Renal Collecting Duct Carcinoma" ) OR TITLE-ABS ( "Sarcomatoid Renal Cell Carcinoma" ) OR TITLE-ABS ( "Mesoblastic Nephroma" ) OR TITLE-ABS ( "Congenital Mesoblastic Nephroma*" ) OR TITLE-ABS ( "Wilms Tumor*" ) OR TITLE-ABS ( nephroblastoma ) OR TITLE-ABS ( "Wilms' Tumor" ) OR TITLE-ABS ( "Wilm's Tumor" ) OR TITLE-ABS ( "Wilm Tumor" ) OR TITLE-ABS ( "Bilateral Wilms Tumor" ) OR TITLE-ABS ( "Denys-Drash Syndrome" ) OR TITLE-ABS ( "Denys Drash Syndrome" ) OR TITLE-ABS ( "WAGR Syndrome" ) OR TITLE-ABS ( "Chromosome 11p13 Deletion Syndrome" ) OR TITLE-ABS ( "11p 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*3) 1 AND 2 AND (DOCTYPE(ar) OR DOCTYPE(re)) AND PUBYEAR < 2025*

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