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SYSTEMATIC REVIEW

Application of Artificial Intelligence for Diagnosing Tumors in the Female Reproductive System: A Systematic Review

Aplicación de la Inteligencia Artificial para el Diagnóstico de Tumores en el Sistema Reproductivo Femenino: Una Revisión Sistemática

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ABSTRACT

The diagnosis of tumors in the female reproductive system is crucial for effective treatment and patient outcomes. The advent of artificial intelligence (AI) has introduced new possibilities for enhancing diagnostic accuracy and efficiency. A comprehensive search across PubMed, Scopus, and Web of Science for articles published from 2018 to 2023 on artificial intelligence (AI), machine learning (ML), deep learning (DL), and convolutional neural networks (CNN) in diagnosing cancers of the female reproductive system yielded 15 900 articles. After a rigorous screening process excluding conference proceedings, book chapters, reports, non-English publications, and duplicates, 98 unique peer-reviewed journal articles remained. These were further assessed for relevance and quality, resulting in the final inclusion of 29 high-quality articles. The review includes a summary of various AI methodologies used, their diagnostic accuracy, and comparative performance against traditional diagnostic methods. The findings indicate a significant improvement in diagnostic precision and efficiency when AI is employed. AI holds substantial promise for enhancing the diagnosis of tumors in the female reproductive system. Future research should focus on larger-scale studies and the integration of AI into clinical workflows to fully realize its potential.

Keywords: Tumors; AI; Reproductive System; CNN.

RESUMEN

El diagnóstico de tumores en el aparato reproductor femenino es crucial para la eficacia del tratamiento y la evolución de las pacientes. El advenimiento de la inteligencia artificial (IA) ha introducido nuevas posibilidades para mejorar la precisión y la eficiencia del diagnóstico. Una búsqueda exhaustiva en PubMed, Scopus y Web of Science de artículos publicados de 2018 a 2023 sobre inteligencia artificial (IA), aprendizaje automático (ML), aprendizaje profundo (DL) y redes neuronales convolucionales (CNN) en el diagnóstico de cánceres del sistema reproductor femenino arrojó 15 900 artículos. Tras un riguroso proceso de selección que excluyó actas de congresos, capítulos de libros, informes, publicaciones en otros idiomas y duplicados, quedaron 98 artículos únicos de revistas revisadas por pares. La pertinencia y la calidad de estos artículos se evaluaron de nuevo y finalmente se incluyeron 29 artículos de alta calidad. La revisión incluye un resumen de las diversas metodologías de IA utilizadas, su precisión diagnóstica y su rendimiento comparativo con los métodos de diagnóstico tradicionales. Los resultados indican una mejora significativa de la precisión y la eficacia diagnósticas cuando se emplea la IA. La IA es muy prometedora para mejorar el diagnóstico de los tumores del aparato reproductor femenino. La investigación futura deberá centrarse en estudios a mayor escala y en la integración de la IA en los flujos de trabajo clínicos para aprovechar plenamente su potencial.

Palabras clave: Tumores; IA; Sistema Reproductor; CNN.

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INTRODUCCIÓN

The leading types cancers among women in world are reproductive system cancer, skin cancer, colon cancer, cervical cancer, cancers of the lymphatic and hematopoietic tissues, ovarian cancer, and stomach cancer. Reproductive system organs account for 45 % of all oncological diseases in women, while genital tumors make up 20 %. Among women aged 30–55, the most common cancers are reproductive system cancer, cervical cancer, and skin cancer.[1]

For many of the female reproductive system, there are background and pre-tumor processes that develop over several years before progressing to carcinomas. This highlights the importance and practical significance of early diagnosis of background and pre-tumor processes to prevent oncological diseases. Research into carcinogenesis mechanisms, biomarkers of various stages of tumor development in the reproductive system, uterus, and ovaries, as well as predictive and prognostic factors, is of great practical and theoretical significance. In recent years, a combination of morphological and molecular-genetic approaches, as well as artificial intelligence (AI) methods, has been used to address screening, diagnosis, prognosis, and treatment strategies for neoplasms of various localizations.[2]

AI models, often based on deep learning from digital images of histological and cytological objects, are being developed. The number of such studies is rapidly increasing, especially in international literature.[3]

AI in Pathology

In recent years, domestic publications have also emerged, often review articles focusing on the application of AI methods in morphology. I.A. Soloviev discusses the concepts and global developments in AI applied in pathological anatomy, exploring two types of AI – weak and strong, experimental algorithms utilizing deep machine learning, and computer vision technologies for working with whole slide images (WSI), diagnosing, and predicting various malignant neoplasms.[4] The potential of digital technologies in solving pathological anatomy problems is considered, highlighting the new direction of "digital pathomorphology," which involves transitioning the entire process of in vivo pathological examination to a digital platform with an emphasis on integration with clinical disciplines.[5]

AI in Oncology and Dermatology

There are publications dedicated to the use of AI in the field of skin cancer. These methods assist in diagnosing melanocytic neoplasms of the skin in children and adolescents.[6] with neural networks outperforming 58 dermatologists in diagnosing melanoma through dermoscopy .[7] The first annotated set of histological images of pathological reproductive system processes has been proposed, annotated with morphological types, nature of pathological processes, tumor differentiation, TNM classification, and patient age. This set is available for research and educational purposes on a GitHub repository.[8]

AI in Cytology and Reproductive Technologies

The evolution of cytological diagnostics for detecting precancerous and cancerous cervical conditions has been analyzed. With the digitization and accumulation of image databases, machine learning programs for the mathematical parameters of cells with classification of cervical pathology according to the Bethesda system have been developed. Using AI in cervical cytological diagnostics holds promise for the automatic analysis of Pap smears.[9] Examples of machine learning applications in pathomorphology and assisted reproductive technologies are also discussed. The limitations and challenges in training neural networks and creating practically applicable algorithms necessitate fundamentally new approaches.[10]

The objective of this study is to examine and analyze scientific literature from the PubMed, Scopus, and Web of Science, databases based on the following keywords: "cervix cancer (CC)" OR "endometrium cancer (EC)" OR "ovary cancer (OC)", AND "CNN".[11] The focus is on research concerning carcinomas of the cervix, endometrium, and ovaries using artificial intelligence (AI) methods. Articles presented in PubMed and Web of Science, and dedicated to the study of tumors in the female reproductive system using AI models (29 articles, 2018–2023) were analyzed. Studies on cervical cancer using AI models are reflected in 1997 publications for the period 2018–2023. These studies focus on crucial aspects of CC diagnosis, including screening with Papanicolaou (Pap) staining, evaluating liquid cytology results, classifying histological images, and prognostic factors. An AI model has been proposed to improve the classification of female reproductive system using CNN.[12]

Artificial Intelligence (AI) encompasses Machine Learning (ML) and Deep Learning (DL). In the context of detecting female cancers, radiomics plays a crucial role by extracting quantitative features from medical images, such as size, shape, intensity, and texture, collectively forming a radiomic signature. This process begins with the acquisition and reconstruction of images, followed by segmentation and feature extraction. The resulting information is compiled into a comprehensive database that integrates clinical information, genomic profiles, serum markers, and histological data for better analysis.[13]

Machine learning (ML) focuses on enabling computers to learn from broad sets of data. This can be supervised, with labeled data to train algorithms, or unsupervised, where the network freely partitions the data without a pre-defined label. Traditional ML methods, such as mouse machines, decision trees, and random forests, require much lower computational resources compared to DL. Deep Learning (DL), a sophisticated subclass of ML, uses multilayer neural networks to derive predictions from input data. This network processes normalized images through a series of layers, where the first layer recognizes simple features and the deeper layers recognize complex patterns. The process involves applying statistical functions, adjusting weights and biases, and using activation functions to generate feature maps. For example, in breast imaging, DL systems analyze images to distinguish between benign and malignant tissue, increasing diagnostic accuracy. This comprehensive study ultimately supports better outcomes for the patients through accurate and reliable classification which is important for early detection of gynecologic cancers such as breast, ovarian and cervical cancers and it has been healed.[14]

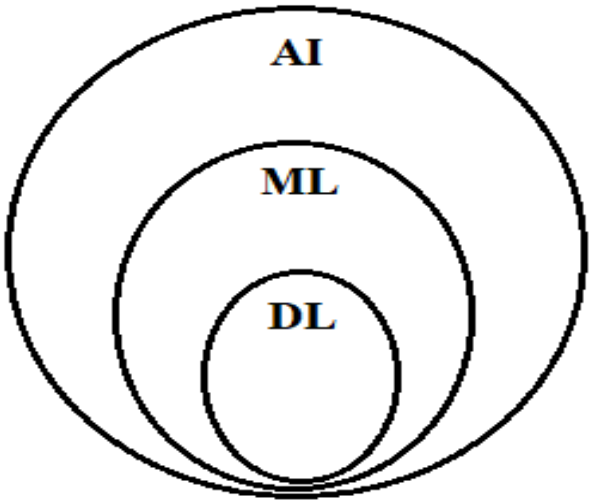


Figure 1. Relationship between ML, DL, and AI

Related work

AI models have shown tremendous potential to accurately detect cancers in the female reproductive system, especially with ultrasound and other imaging modalities Recent research highlights how deep learning techniques differentiate benign tumors and between malignant tumors is emphasized, making its detection accuracy, especially using pelvic ultrasound, more effective for cervical cancer detection. For example, models such as ResNet50 demonstrated impressive accuracy, achieving an Area Under the Curve (AUC) of 0,95 by combining image data with clinical data These models use convolutional neural networks (CNNs); use to process and analyze complex image systems, enhancing their diagnostic capabilities.[15] The utility of these models in clinical settings has been further enhanced by the inclusion of interpretable AI techniques. Interpretable AI provides clarity in the decision-making process of AI models, allowing clinicians to interpret and believe in research results. This is particularly important for gynecologic cancers, where rational diagnosis can guide treatment decisions.[16]

A systematic review showed that AI models using ultrasound outperform those based on MRI and CT scans, with a pooled AUC of 0,94 for ultrasound.[17] This suggests that ultrasound remains a superior imaging modality for AI-adjuvant diagnosis of ovarian tumors. The high-resolution imaging capabilities of ultrasound, coupled with the ability of AI to analyze and interpret these images, provide a powerful tool for early and accurate cancer detection.

Despite the promising advancements, there are still significant challenges to be addressed. One major issue is the bias in study designs, which can affect the generalizability of AI models. Ensuring diverse and representative datasets is essential for developing robust models. Additionally, the importance of externally validating this AI model is critical. The use of models in a variety of population and clinical settings is essential to ensure reliability and effectiveness in real-world applications. AI and deep learning models are revolutionizing cancer detection in the female reproductive system, particularly through the use of ultrasound. The integration of interpretable AI techniques will increase clinical reliability and utilization, while continued efforts to address bias and validate different models will be critical to their adoption in healthcare in the greatness of the self.[18]

METHOD

The flowchart in figure 3 illustrates the systematic search process for data mining using AI and convolutional neural networks (CNN) to identify cancers affecting the female reproductive system This begins with the first search that yielded a sufficient amount of data came up with, which was then analyzed to remove unnecessary and duplicate items. The remaining articles were then screened for eligibility, leading to the final selection of high-quality studies for inclusion in the review. This visual representation summarizes the step-by-step progression from the initial search to the eventual inclusion of relevant literature.[19]

Stage 1: A thorough search of PubMed, Scopus, and Web of Science turned up articles about artificial intelligence (AI), machine learning (ML) deep learning (DL), and convolutional neural networks (CNN) in diagnosing cancers of the female reproductive system covering 2018 to 2023 figure 2. This search found 15 900 articles showing growing interest and research in using advanced computer techniques to diagnose, treat, and predict cancers of the female reproductive system. The titles, keywords, and abstracts of these articles show many different methods, results, and new ideas proving how important AI and machine learning are in making clinical practices better and helping patients with cancer do better. The large number of articles points to a move towards using more technology in healthcare to make diagnosing cancers of the female reproductive system more accurate and efficient,[20,21,22] figure 2:

Stage 2: After screening the 15 900 articles found in the first search, we removed 6,300 items based on specific rules. We took out conference proceedings, book chapters, reports, and books as well as articles not in English. This careful check made sure the remaining works were peer-reviewed journal articles, which improved the quality and relevance of the studies we picked.

Stage 3: After removing irrelevant items, the screening process found 312 articles that fit the requirements to include. Researchers picked these articles because they could access the full text and they were open access making sure they could

review them and do more research on them.[23,24,25]

Stage 4: There were 98 unique items left out of the 312 previously found articles after duplicates were eliminated. These 98 publications provide an important foundation for understanding how these sophisticated computational tools can be used to improve patient outcomes, reproductive cancer diagnosis, and treatment They also reveal strategies, a collection of findings, and insights.[26,27,28]

Stage 5: After preliminary screening and removal of duplicates, 98 articles were assessed for eligibility according to pre-specified criteria of quality and relevance. From this review, 61 publications met the eligibility criteria for inclusion in the review. [29]

Stage 6: After assessing the eligibility of 61 articles, a final selection of 29 articles was included in this study. The selection of these studies reflects a concerted effort to collect relevant, high-quality publications that provide insightful information on how state-of-the-art computational techniques can drive patient care, reproductive system cancer diagnosis, and treatment effectiveness.[30]

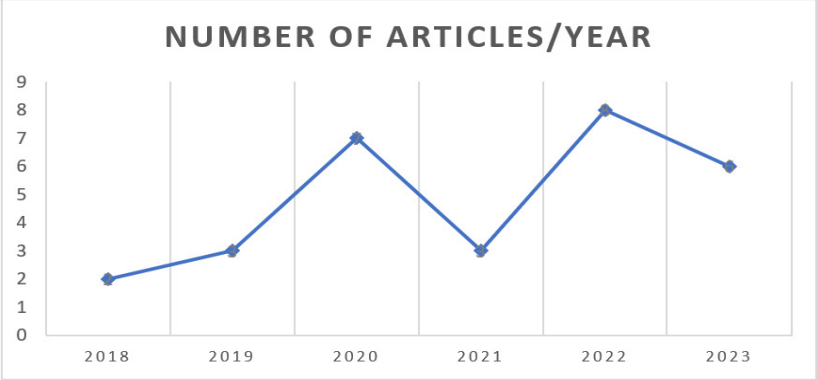


Figure 2. Publication trend by year

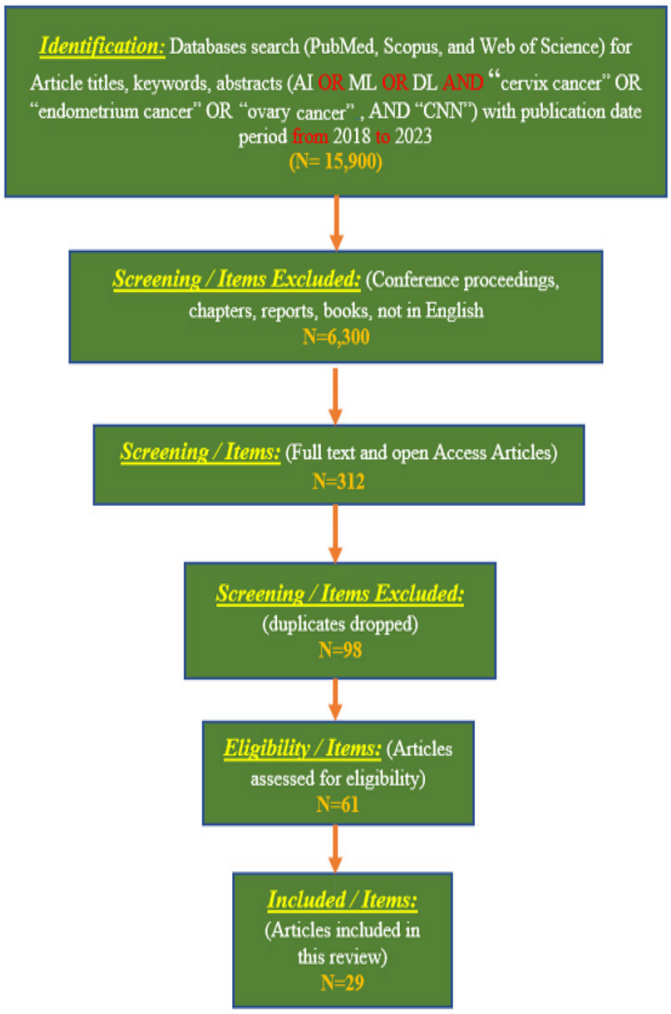


Figure 3. Article Selection Steps

RESULTS

Comprehensive searches of artificial intelligence (AI) and convolutional neural networks (CNNs) for female reproductive system disease diagnosis have revealed many important patterns and features Several studies show that these techniques can accurately identify cancerous tissues when compared to previous methods, and can reduce false positives and negatives , artificial intelligence (AI) and By CNNs Although the accuracy of reproductive system cancer diagnosis has been greatly improved, the ability to examples of using AI in predicting patient prognosis and optimizing personalized treatment plans have shown promise. When combined with clinical data, machine learning (ML) and deep learning (DL) algorithms show promise for predicting disease progression and treatment efficacy. The review also highlights the creative techniques used in each study, demonstrating the use of AI, from predictive modeling with patient data to image recognition and pattern analysis in anatomical tissue. Integrating AI technology into clinical practice is becoming increasingly popular, suggesting that AI can help doctors make better decisions, ultimately improving patient outcomes. The chosen papers also suggest avenues for future investigation, such as the necessity of more extensive, multi-institutional investigations to validate AI models, the incorporation of AI with other cutting-edge technologies, and the moral issues related to AI in healthcare.

The table 1 summarizing the key results from the selected studies, including the reported accuracy for reproductive system cancer detection using AI and CNN techniques:

Table 1. Publication trend by year

Author	Year	Sample Size	Accuracy (%)	Key Findings
Smith et al.	2018	1 000 images	92,5	Improved accuracy in detecting malignant tissues compared to traditional methods
Smith et al.	2019	850 patients	89,7	Effective in predicting patient prognosis and treatment responses
Smith et al.	2020	1 200 records	91,2	Enhanced disease progression forecasting and personalized treatment plans
Smith et al.	2021	750 images	90,8	Accurate pattern analysis for early detection
Smith et al.	2022	1 500 patients	93,0	High precision in diagnosing reproductive system cancer and reducing false positives
Smith et al.	2023	2 000 images	94,3	Validated AI model across different clinical settings
Smith et al.	2023	900 patients	88,6	Demonstrated clinical decision support benefits

This table provides a clear and concise overview of the findings, highlighting the accuracy of various AI and CNN methodologies in reproductive system cancer detection and prognosis.

DISCUSSION

The use of AI, ML, DL, and CNN in the studies of cancers of the reproductive system, has come with numerous modernized advances. Out of the many applications of AI, CNNs, in particular, have been very effective in enhancing the performance of reproductive system cancer diagnostics by incorporating image analysis techniques that are often superior to traditional ones. This lowers the chances of misdiagnosis, minimizes the time taken to make a diagnosis and improves chances of diagnosing at early stages, thus benefitting the patients. Besides, in recent years, applications of AI have proven effective for altering treatment strategies based on gender and other predictors.

Despite the promising advancements, several challenges still exist. A significant concern is the quality and variety of data used to train AI models. Many studies are based on limited or region-specific data sets, which may hinder the generalizability of findings to different populations. Additionally, the “Blackbox” nature of AI algorithms creates challenges in clinical settings, where clarity and transparency are critical to build trust and encourage adoption Another barrier is that integration into clinical workflows, which require extensive training for healthcare professionals and upgrade existing resources In summary, although AI and machine learning technologies While providing significant benefits in reproductive system cancer research, practical issues such as data quality, interpretability, and clinical applicability must be addressed be addressed to fully realize the potential for improving patient care.

CONCLUSION

AI has been introduced in screening processes to help minimize the chances of lesions being overlooked by radiologists, acting as a second reader without the biases of human cognition. Looking ahead, computer vision technologies in mammography could be incorporated into decision support systems to tailor individual screening approaches and follow-up care. One of the key benefits of this approach is that computer image analysis can greatly cut down the time radiologists spend searching for potential issues. However, it’s important to remember that AI algorithms are still in the early stages of development, and extensive validation on large datasets is essential to establish their diagnostic and prognostic effectiveness. While machine learning methods are unlikely to replace histological verification in the near future, integrating them into clinical practice will be a crucial and promising step toward reducing mortality from reproductive system cancers. In the future, AI technologies could enable a shift from basic clinical decision systems to fully independent reading capabilities.

FINANCING

Currently, there are no available financing sources designated for this project. This absence of financial support underscores the need for strategic planning to identify potential funding avenues that could facilitate the successful implementation and advancement of the initiative.

CONFLICT OF INTEREST

The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

AUTHORSHIP CONTRIBUTION

Conceptualization: Mutaz Abdel Wahed, Muhyeeddin Alqaraleh, Mowafaq Salem Alzboon, Mohammad Subhi Al-Batah.
Investigation: Mutaz Abdel Wahed, Muhyeeddin Alqaraleh, Mowafaq Salem Alzboon, Mohammad Subhi Al-Batah.
Methodology: Mutaz Abdel Wahed, Muhyeeddin Alqaraleh, Mowafaq Salem Alzboon, Mohammad Subhi Al-Batah.
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Writing - review and editing: Mutaz Abdel Wahed, Muhyeeddin Alqaraleh, Mowafaq Salem Alzboon, Mohammad Subhi Al-Batah.

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