Revista de Ciencias Médicas de Pinar del Río

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6745

REVIEW ARTICLE

Cancer diagnostics advances in molecular and imaging methods for early detection

Diagnóstico del cáncer avances en métodos moleculares y de imagen para una detección temprana

Ricardo Alexander Carrillo-Ruiz[1], **Stiven Paul Guevara-Hernández**[1], **Alvaro Paul Moina-Veloz** [1]

[1]Universidad Regional Autónoma de los Andes. Facultad de Medicina. Ambato. Ecuador

Received: April 21, 2025
Accepted: April 23, 2025
Published: April 25, 2025

Citar como: Carrillo-Ruiz RA, Guevara-Hernández SP, Moina-Veloz AP. Diagnóstico del cáncer avances en métodos moleculares y de imagen para una detección temprana. Rev Ciencias Médicas [Internet]. 2025 [citado: fecha de acceso]; 29(2025): e6745. Disponible en: http://revcmpinar.sld.cu/index.php/publicaciones/article/view/6745

ABSTRACT

Introduction: cancer is the rapid multiplication of abnormal cells that spread beyond their usual limits and can invade adjacent parts of the body or spread to other organs, in a process called metastasis. The spread of metastases is the main cause of death from the disease. There are different methods of cancer diagnosis, but in this research we will focus on molecular and imaging methods.
Objective: to analyze advances in molecular and imaging diagnosis of cancer.
Methods: analysis of original articles and bibliographic reviews previously carried out that provided information on the advances in molecular and imaging diagnosis of cancer, in addition, the search for information in different databases such as Scielo, Elsevier, PubMed, Chrocane, Epistemonikos, and different journals including Seimic, Medigraphic Artemisa, Recimundo, SCIENCE, MEDICRIT was prioritized**.**
Development: the importance of an integral diagnostic approach is emphasized, considering the high lethality rate of this disease. Diagnosis will focus on the various imaging techniques and biomolecular studies adopted to prevent and diagnose this disease, and the use of artificial intelligence for early diagnosis of these entities is also addressed.
Conclusions: advances in molecular and imaging diagnosis of cancer are marking a significant milestone in the quest for more efficient and earlier detection of this disease.

Keywords: Cancer; Ultrasonography; Technological Development.

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6745

RESUMEN

Introducción: el cáncer es la multiplicación rápida de células anormales que se extienden más allá de sus límites habituales y pueden invadir partes adyacentes del cuerpo o propagarse a otros órganos, en un proceso que se denomina metástasis. La extensión de las metástasis es la principal causa de muerte por la enfermedad. Existen distintos métodos de diagnóstico del cáncer, pero en esta investigación nos centraremos en los métodos moleculares y de imagen.
Objetivo: analizar los avances en el diagnóstico molecular y de imagen del cáncer.
Métodos: análisis de artículos originales y revisiones bibliográficas previamente realizadas que aportaron una información sobre los avances de en el diagnóstico molecular y de imagen del cáncer, además se priorizó la búsqueda de información en diferentes bases de datos como Scielo, Elsevier, PubMed, Chrocane, Epistemonikos, y diferentes revistas entre ellas Seimic, Medigraphic Artemisa, Recimundo, SCIENCE, MEDICRIT.
Desarrollo: se destaca la importancia de un enfoque de diagnóstico integral, considerando la alta tasa de letalidad de esta enfermedad. El diagnostico se enfocará en las diversas técnicas de imagen y de estudios biomoleculares que se adoptan para prevenir y diagnosticar dicha enfermedad, además se aborda el empleo de la inteligencia artificial para el diagnóstico temprano de dichas entidades.
Conclusiones: Los avances en el diagnóstico molecular y de imagen del cáncer están marcando un hito significativo en la búsqueda de una detección más eficiente y precoz de esta enfermedad.

Palabras clave*:* Cáncer; Imagen Médica; Avances Tecnológicos.

INTRODUCTION

Cancer is the rapid multiplication of abnormal cells that spread beyond their normal boundaries and can invade adjacent parts of the body or spread to other organs, a process called metastasis. The spread of metastasis is the leading cause of death from the disease. There are various methods for diagnosing cancer, but in this study, we will focus on molecular and imaging methods.

Molecular testing results provide doctors with the information they need to identify genes that have changed (mutated). By identifying these mutations, doctors can determine the best treatment options for specific patients.[1] Diagnosing cancer often requires imaging tests, many of which use small amounts of radiation. Procedures such as X-rays, computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), and single-photon emission computed tomography (SPECT) are important for making clinical decisions, such as regarding treatment and follow-up.[2]

Recent advances in the field of artificial intelligence have generated great excitement in the healthcare sector, especially regarding breast cancer detection. AI has emerged as a promising tool for improving diagnostic accuracy and, consequently, improving patients' lives. AI has become a key tool in breast cancer detection. It can automate image analysis, personalize diagnoses, and, most importantly, predict prognosis.[3]

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6745

Cancer remains one of the leading causes of death. Molecular and imaging methods have emerged as fundamental tools in its early detection and treatment. Circulating biomarkers and magnetic nanoparticles are revolutionizing diagnosis by offering less invasive alternatives and improving detection sensitivity. Furthermore, new technologies such as artificial intelligence are showing promise in improving diagnostic accuracy, especially in difficult cancers such as pancreatic and gallbladder cancers. This study employed a rigorous approach based on a systematic review of observational studies and controlled clinical trials.

Molecular testing may not be appropriate, and may not be available, for all patients or all types of cancer. Patients should speak with their treating physicians to determine if molecular testing is an appropriate option for them.

Based on what has been expressed up to here, the objective of the research is:analyze advances in molecular diagnosis and cancer imaging

METHODS

A bibliographic review was carried out in which the analysis of original articles and previously carried out bibliographic reviews was executed that provided information on the advances in the molecular diagnosis and imaging of cancer, in addition, the search for information was prioritized in different databases such as Scielo, Elsevier, PubMed, Chrocane, Epistemonikos, and different journals including Seimic, Medigraphic Artemisa, Recimundo, SCIENCE, MEDICRIT, articles published from 2020 to March 2024 using the following keywords: Cancer; Early detection; Molecular methods; Medical imaging; Technological advances.

The keywords were searched individually, and then the search was repeated in association with each keyword. Papers unsuitable for the review were excluded. Articles were selected independently by two co-authors, and their subsequent selection was unanimous and collaborative.

DEVELOPMENT

Cortés Morera et al.,[4] raise the usefulness of screening, as well as the main imaging studies available by the authors, stating that Ovarian cancer has been identified as the gynecological neoplasia with a particularly challenging prognosis. This difficulty derives, to a large extent, from the asymptomatic nature that often characterizes this disease, which leads to diagnoses in advanced stages. The evidence gathered suggests that advances in therapies have not significantly improved the survival of patients with ovarian cancer. This scenario drives the constant search for methods that facilitate screening and early detection of the pathology. Despite this effort, the lack of a cost-effective method for screening has limited its application in the general population, reserving it mainly for specific cases, such as women with a family history of the disease or hereditary syndromes.

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6745

This review also addresses the various imaging techniques used in the study and characterization of adnexal masses, as well as in the staging and prognosis of ovarian cancer. Among the techniques evaluated, ultrasound (US) stands out as the preferred option for the initial evaluation of adnexal masses. However, regarding staging, computed tomography (CT) and magnetic resonance imaging (MRI) are observed to be superior to ultrasound.

For Sánchez GA.,[5] in his research he proposes to explore aspects related to the epidemiology of lung cancer, also addressing genetic and molecular factors that influence its origin, development, prognosis and survival. It was carried out using a bibliographic documentary methodology and in review mode, focusing on highlighting innovations in diagnosis, emphasizing those that improve primary detection. Outstanding therapeutic alternatives and the innovations achieved to date are addressed.

In the field of diagnostic imaging, techniques such as bronchoscopic sonography, transesophageal sonography, and positron emission tomography fused with computed tomography stand out. Traditional methods for confirming early diagnosis include percutaneous aspiration biopsy and bronchoscopy. Primary diagnosis, crucial for surgical interventions in early stages, favors excellent survival in patients considered eligible after a thorough evaluation of surgical risk and other factors. Multidisciplinary treatment includes surgery, chemotherapy, and radiotherapy in moderately advanced stages, while in more advanced stages, chemotherapy and radiotherapy play a palliative role, impacting quality of life and eventual survival.[5]

A study by Cárdenas-Sánchez,[6] highlights the crucial importance of an accurate and early diagnosis, as well as the prompt initiation of appropriate treatment. Research has conclusively demonstrated that any delay in starting treatment negatively impacts survival rates. This emphasis underscores the urgency of rapid intervention to optimize outcomes and highlights the vital relationship between time to diagnosis and treatment effectiveness in the fight against breast cancer.

For Necula L,[7] proposes a synthesis of the newly identified circulating molecules, including microRNAs, long non-coding RNAs and circular RNAs. These discoveries have the potential to revolutionize the early diagnosis of gastric cancer (GC). Despite this, currently available circulating biomarkers for the diagnosis and prognosis of GC show limited sensitivity and specificity. The diagnostic process for GC largely depends on invasive procedures such as upper gastrointestinal endoscopy. There is an urgent demand for less or non-invasive tests and the identification of highly specific biomarkers for the detection of GC.
.
Body fluids, such as peripheral blood, urine, saliva, and gastric lavage/gastric juice, are emerging as potential sources of specific biomarkers. These fluids could provide crucial information for the screening and diagnosis of GC, offering a less invasive alternative to current methods. Exploring circulating molecules and developing accurate biomarkers hold significant promise for advancing early diagnostic strategies in gastric cancer.[7]

It is important to emphasize that diagnosis, in most cases, is not immediate, which leads to the frequent identification of situations in which treatment may become less effective. In this context, regular visits to the doctor and additional examinations could play a crucial role in disease prevention. Early detection and the adoption of preventive measures based on constant monitoring can be key to improving the prognosis and the effectiveness of available treatments.[8]

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6745

Artificial intelligence and machine learning techniques are disrupting biomedical research and healthcare, with potentially revolutionary applications in cancer and oncology research. Potential applications in this field are broad and include cancer detection and diagnosis, subtyping, optimization of cancer treatments, and identification of new therapeutic targets in drug discovery.[9]

This opinion piece presents the perspectives of four experts on how we can begin to implement artificial intelligence, while ensuring high standards are maintained. The goal is to transform cancer diagnosis, as well as the prognosis and treatment of cancer patients, and to enhance biological discoveries. The convergence of artificial intelligence and oncology presents a promising outlook, but it is essential to carefully address the challenges to ensure the effective and ethical implementation of these innovative technologies in cancer research and care.[9]

Recent advances in nanotechnology have led to the development of next-generation magnetic nanoparticles (MNPs), suitable for various biomedical applications. This review explores the methods used in MNP fabrication and design. Furthermore, a critical assessment is made of recent advances in the use of MNPs for hyperthermia therapy, drug release monitoring, magnetic resonance imaging (MRI), and biosensing. Finally, the challenges in this field are addressed, and potential opportunities for improving MNP properties are discussed.

In the article by Loveday et al.,[10] the focus is on the 95 % of pancreatic cancer cases that present as pancreatic ductal adenocarcinoma, with the aim of summarizing current recommendations for diagnosis and treatment. Weight loss combined with abdominal symptoms or back pain in individuals aged 60 years or older requires urgent abdominal CT scanning. Similarly, individuals aged 40 years or older with jaundice require direct referral to specialists. Pancreatic cancer is classified as resectable, borderline resectable, locally advanced, or metastatic. Resectable disease is treated with surgical resection and adjuvant chemotherapy. Metastatic and unresectable disease is treated with chemotherapy or optimal supportive care. Most patients require nutritional support.

Regarding diagnosis, various imaging techniques such as ultrasound (US), computed tomography (CT) and magnetic resonance imaging (MRI) are used, all of which are very useful for obtaining detailed information. Tumor markers have been incorporated as an integral part of the diagnostic process, providing support both in monitoring and in predicting the prognosis in certain cases. It is concluded that, in the initial stages, the preferred therapeutic option is surgery. It is relevant to note that, in many cases, the detection of this disease occurs incidentally during routine cholecystectomies performed for cholelithiasis.[11]

There is an increasing number of studies focusing on the identification of novel serum biomarkers and exploring their combination with CA19-9 for the detection of pancreatic cancer. Furthermore, the application of liquid biopsy, which involves circulating tumor cells (CTCs), circulating tumor DNA (ctDNA), microRNAs (miRNAs), and exosomes in blood, as well as biomarkers in urine and saliva, is attracting increasing attention in the diagnosis of pancreatic cancer.[11]

Additionally, many innovative technologies, such as artificial intelligence, computer-aided diagnostic systems, metabolomic technology, technologies associated with ion mobility spectrometry (IMS) and new nanomaterials, have been tested for the early diagnosis of pancreatic cancer, showing promising prospects.[12]

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6745

Based on a compilation of relevant studies, it is possible to demonstrate the significant progress made in the early detection of different types of cancer. In the field of early diagnosis of gastric cancer, advances in molecular and imaging methods have sparked considerable interest in the scientific community. Early detection of this disease is essential to improve prognoses and the efficacy of available treatments. A review of recent advances highlights the potential of circulating molecules, such as microRNAs, long non-coding RNAs, and circular RNAs, as promising biomarkers for the early diagnosis of GC. However, it is recognized that current circulating biomarkers show limitations in sensitivity and specificity, underscoring the need to identify more accurate markers.(7)

The examination of bodily fluids, such as peripheral blood, urine, and gastric lavage, is emerging as a promising avenue for the search for specific biomarkers, offering less invasive alternatives to current diagnostic methods, which are primarily based on endoscopic procedures. The search for accurate, noninvasive biomarkers represents a crucial step toward more effective early detection strategies, which could significantly improve clinical outcomes.(7)

On the other hand, the case of gastric cancer highlights the importance of public education on healthy lifestyle habits and regular medical visits for early diagnosis. Lack of immediate diagnosis leads to delayed identification of the disease, which can compromise the effectiveness of treatment. Prevention and early detection through regular screening are essential for improving prognosis and reducing the burden of the disease.(8)

Regarding the application of artificial intelligence in cancer diagnosis, transformative potential is emerging. AI offers powerful tools for tumor detection and classification, as well as for treatment optimization and the identification of new therapeutic targets. However, its implementation must be approached with caution to ensure accuracy and ethical use. The convergence of AI and oncology promises to significantly improve medical care and outcomes for cancer patients, but addressing the challenges associated with its integration into clinical practice is crucial.(9)

Another review of this nature highlights the variety of AI approaches used to predict cancer, from conventional machine learning to deep learning. Despite promising results, limitations are identified in the existing literature, highlighting the need for additional research to address the challenges in this field.(13)

The use of magnetic nanoparticles has emerged as a promising tool in the early diagnosis and initial treatment of cancer. Nanotechnology has enabled significant advances in the design and fabrication of MNPs with versatile biomedical applications. A recent review explored the methods for fabricating and designing MNPs, as well as advances in their application to hyperthermia therapy, drug release control, magnetic resonance imaging, and biosensing. Hyperthermia therapy, which involves the controlled heating of cancerous tissues by MNPs under the influence of a magnetic field, shows promise for selectively destroying tumor cells. Furthermore, MNPs can be used as targeted drug delivery systems, enabling the specific delivery of therapeutic agents to tumor sites.(14)

However, despite these advances, there are significant challenges in the clinical implementation of MNPs. Optimizing their physical and chemical properties is critical to ensuring their efficacy and safety in biomedical applications. Furthermore, properly characterizing the biological response to MNPs is essential to understanding their in vivo behavior and minimizing potential adverse effects.

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6745

For pancreatic cancer, which has one of the worst prognoses of all cancers, updating diagnostic methods is crucial to improving survival rates. The review highlights the importance of abdominal CT in patients over 60 years of age with weight loss and abdominal symptoms or back pain. Furthermore, it emphasizes the need for immediate referral to specialists in cases of jaundice in people over 40 years of age.[13]

Early diagnosis of gallbladder and pancreatic cancer remains a major challenge in clinical practice, but advances in detection methods are offering new hope in the fight against these diseases. In the Chilean context, imaging techniques such as ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) are used to obtain detailed information about the disease. Furthermore, tumor markers have been incorporated to support the diagnostic process and follow-up of specific cases. The incidental detection of gallbladder cancer during routine cholecystectomies performed for cholelithiasis highlights the importance of surveillance and early diagnosis of this disease. In many cases, surgery remains the preferred therapeutic option in the early stages.[12]

On the other hand, pancreatic cancer presents an even greater challenge due to its late and often aggressive diagnosis. However, recent advances in detection methods, including imaging techniques, pathological examinations, and liquid biopsy, are beginning to change the landscape. There is an increase in research focused on the identification of novel serum biomarkers and the application of liquid biopsy, which includes circulating tumor cells (CTCs), circulating tumor DNA (ctDNA), microRNAs (miRNAs), and exosomes in blood, urine, and saliva.[12]

The classification and treatment of pancreatic cancer varies depending on the stage of the disease. While resectable disease is treated with surgical resection and adjuvant chemotherapy, metastatic and unresectable disease is managed with chemotherapy or optimal supportive care. However, the need for additional research to improve therapeutic strategies and address the challenges associated with this aggressive cancer is recognized.

The application of innovative technologies such as artificial intelligence, computer-assisted diagnostic systems, and metabolomics, among others, offers new perspectives for the early diagnosis of pancreatic cancer. These tools can improve diagnostic accuracy and efficiency, which is crucial for improving clinical outcomes and patient survival.

However, despite these promising advances, significant challenges remain in the early diagnosis of both types of cancer. Continued research and cross-disciplinary collaboration are critical to developing more effective screening and diagnostic strategies. Furthermore, public awareness of the symptoms and risk factors associated with these cancers can play a crucial role in early detection and timely treatment.

CONCLUSIONS

Advances in molecular diagnostics and cancer imaging are marking a significant milestone in the quest for more efficient and early detection of this disease

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6745

BIBLIOGRAPHIC REFERENCES

1. Leukemia y Lymphoma Society. Leukemia y Lymphoma. In.; 2018. p. 1-7.

2. Centro Diagnostico. Explorando los avances mas recientes en la deteccion del Cancer de Mama [Internet]. Centro de Diagnostico; 2023 [citado 20/03/2025]. Disponible en: https://centrodiagnostico.com/prensa/explorando-los-avances-mas-recientes-en-la-deteccion-del-cancer-de-mama/

3. Organismo Internacional de Energía Atómica. Diagnóstico del cáncer [Internet]. IAEA; 2019 [citado 20/03/2025]. Disponible en: https://www.iaea.org/es/temas/diagnostico-del-cancer

4. Morera A, Ibáñez Morera M, Hernández Lara A, García Carranza MA. Cáncer de Ovario: Tamizaje y diagnóstico imagenológico. Med. leg. Costa Rica [Internet]. 2020 Mar [cited 20/03/2025]; 37(1): 54-61. Available from: http://www.scielo.sa.cr/scielo.php?script=sci_arttext&pid=S1409-00152020000100054&lng=en

5. Sanchez GA, Ugarte Palacios CV, Ugarte Palacios NA, Morales Labre KO. Cáncer de pulmón y su importancia en el diagnóstico primario. RECIAMUC [Internet]. 23 de mayo de 2022 [citado 20/03/2025]; 6(2): 208-17. Disponible en: https://reciamuc.com/index.php/RECIAMUC/article/view/854

6. Cárdenas-Sánchez J, Valle-Solís Aura AE, Arce-Salinas C, Bargalló-Rocha JE, Bautista-Piña V, Cervantes-Sánchez G, et al. Consenso Mexicano sobre diagnóstico y tratamiento del cáncer mamario. Octava revisión. Colima 2019. Gac. mex. oncol. [Internet]. 2019 Sep [citado 20/03/2025]; 18(3): 141-231. Disponible en: http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2565-005X2019000300141&lng=es

7. L, Matei L, Dragu D, Neagu AI, Mambet C, Nedeianu S, et al. Recent advances in gastric cancer early diagnosis. World J Gastroenterol [Internet]. 2019 May 7 [citado 20/03/2025]; 25(17): 2029-2044. Disponible en: https://pmc.ncbi.nlm.nih.gov/articles/PMC6506585/

8. Cardenas Martinez CE, Cardenas Davalos JC, Jativa Sanchez JJ. Cáncer Gástrico: una revisión bibliográfica. Dominio de las Ciencias [Internet]. 2021 [citado 2025 Abr 220/03/20255]; 7(1): 338-354. Disponible en: file:///C:/Users/User/Downloads/Dialnet-CancerGastrico-8231665.pdf

9. Elemento O, Leslie C, Lundin J, Tourassi G. Artificial intelligence in cancer research, diagnosis and therapy. Nat Rev Cancer [Internet]. 2021 Dec [citado 20/03/2025]; 21(12): 747-752. Disponible en: https://pubmed.ncbi.nlm.nih.gov/34535775/

10. Loveday BPT, Lipton L, Thomson BN. Pancreatic cancer: An update on diagnosis and management. Aust J Gen Pract [Internet]. 2019 Dec [citado 20/03/2025]; 48(12): 826-831. Dissponible en: https://pubmed.ncbi.nlm.nih.gov/31774983/

11. Hernadez Salcedo MI, Almeida Barba KE,Castillo Gonzalez AM,Freire Sandoval AR. Diagnóstico y tratamiento de cáncer de vesícula biliar. Recimundo [Internet]. 2020 [citado 20/03/2025]; 4(1): 236-249. Disponible en: https://recimundo.com/index.php/es/article/view/797

ISSN: 1561-3194 **RNPS:** 1877
Rev Ciencias Médicas. 2025; 29(2025): e6745

12. Yang J, Xu R, Wang C, Qiu J, Ren B, You L. Early screening and diagnosis strategies of pancreatic cancer: a comprehensive review. Cancer Commun (Lond) [Internet]. 2021 Dec [citado 20/03/2025]; 41(12): 1257-1274. Disponible en: https://pubmed.ncbi.nlm.nih.gov/34331845/

13. Kumar Y, Gupta S, Singla R, Hu YC. A Systematic Review of Artificial Intelligence Techniques in Cancer Prediction and Diagnosis. Arch Comput Methods Eng [Internet]. 2022 [citado 20/03/2025]; 29(4): 2043-2070. Disponible en: https://pubmed.ncbi.nlm.nih.gov/34602811/

14. Farzin A, Etesami SA, Quint J, Memic A, Tamayol A. Magnetic Nanoparticles in Cancer Therapy and Diagnosis. Adv Healthc Mater [Internet]. 2020 May [citado 2025 Abr 220/03/20255]; 9(9): e1901058. Disponible en: https://pubmed.ncbi.nlm.nih.gov/32196144/