Mini Review

Can AI help breast cancer research?

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Introduction

Breast cancer remains one of the most pervasive and challenging diseases affecting women worldwide. Despite significant advances in treatment and diagnosis, breast cancer continues to be a major public health concern, necessitating ongoing research and innovation. This editorial delves into the current global landscape of breast cancer research, highlighting key developments, persistent challenges, Involvement of Artificial Intelligence and future directions.

Advances in diagnosis and screening

Over the past few decades, advancements in diagnostic technologies have significantly improved early detection rates. Mammography remains the gold standard for breast cancer screening, but new imaging techniques such as digital breast tomosynthesis (3D mammography), magnetic resonance imaging (MRI), and molecular breast imaging (MBI) are enhancing the accuracy of diagnosis.[1,2] These innovations allow for better visualization of breast tissues, particularly in women with dense breast tissue, thereby facilitating earlier and more accurate detection of malignancies.

Imaging techniques

A. Mammography

I. Standard Mammography: The gold standard for breast cancer screening, mammography uses low-dose X-rays to create detailed images of the breast. It is effective in detecting tumors that are too small to be felt.

II. Digital Breast Tomosynthesis (3D Mammography): An advanced form of mammography that captures multiple images of the breast from different angles, creating a three-dimensional picture. This method improves cancer detection, especially in women with dense breast tissue.

B. Magnetic Resonance Imaging (MRI)

MRI uses magnetic fields and radio waves to produce detailed images of the breast. It is highly sensitive and can be particularly useful for women with a high risk of breast cancer or those with dense breast tissue. MRI is often used in conjunction with other imaging methods to provide a more comprehensive evaluation.

C. Ultrasound

This technique uses high-frequency sound waves to produce images of the breast. It is often used to evaluate abnormalities found in mammography or physical exams and can help distinguish between solid masses and fluid-filled cysts.

D. Molecular Breast Imaging (MBI)

MBI is a nuclear medicine technique that uses a radioactive tracer to detect cancerous cells in the breast. This method is particularly beneficial for women with dense breast tissue where traditional mammography might be less effective.

Biopsy procedures

A. Fine needle aspiration (FNA)

A minimally invasive procedure that uses a thin needle to extract cells from a suspicious area in the breast. The cells are then examined under a microscope to determine if they are cancerous.

B. Core needle biopsy

This procedure uses a larger needle to remove a core of tissue from the suspicious area. It provides more information than FNA because it extracts a larger sample, allowing for a more detailed analysis.

C. Surgical biopsy

If less invasive methods are inconclusive, a surgical biopsy may be performed to remove a part or all of a suspicious lump. This procedure can be either an incisional biopsy (removing part of the lump) or an excisional biopsy (removing the entire lump).

Molecular and genetic testing

A. Hormone receptor tests

Tests to determine if the breast cancer cells have receptors for the hormones estrogen and progesterone. Hormone receptor-positive cancers can be treated with hormone therapies that block these receptors.

B. HER2 Testing

HER2 (human epidermal growth factor receptor 2) is a protein that promotes the growth of cancer cells. Testing for HER2 can identify cancers that may benefit from targeted therapies like trastuzumab (Herceptin) and pertuzumab (Perjeta).

C. Genomic profiling

Techniques such as next-generation sequencing can analyze the genetic makeup of the cancer cells to identify specific mutations and biomarkers. This helps in tailoring personalized treatment plans and predicting the likelihood of recurrence.

Personalized medicine and targeted therapies

The era of personalized medicine has ushered in a paradigm shift in breast cancer treatment. Researchers are increasingly focusing on the molecular and genetic underpinnings of breast cancer, leading to the development of targeted therapies. Hormone receptor-positive breast cancers, for instance, can be treated with hormone therapies such as tamoxifen or aromatase inhibitors. HER2-positive breast cancers, on the other hand, benefit from HER2-targeted therapies like trastuzumab (Herceptin) and pertuzumab (Perjeta).[3]

Moreover, the advent of genomic profiling and next-generation sequencing has enabled the identification of specific genetic mutations and biomarkers associated with breast cancer. This precision medicine approach not only improves treatment efficacy but also reduces the risk of adverse effects, as therapies are tailored to the individual patient's genetic profile.[4,5]

Immunotherapy: a new frontier

Immunotherapy, which harnesses the body's immune system to fight cancer, has shown promise in breast cancer treatment. The approval of immune checkpoint inhibitors, such as pembrolizumab (Keytruda), for certain types of breast cancer marks a significant milestone.[6] Ongoing research is exploring combination therapies that pair immunotherapy with conventional treatments like chemotherapy and radiation, with the aim of enhancing therapeutic outcomes.[7]

Disparities in breast cancer outcomes

Despite these advancements, disparities in breast cancer outcomes persist globally. Socioeconomic factors, healthcare access, and differences in healthcare infrastructure contribute to significant variations in survival rates between high-income and low- and middle-income countries. In many developing regions, limited access to screening and treatment facilities results in late-stage diagnoses and poorer prognoses.[8,9] Addressing these disparities requires a multifaceted approach, including increasing awareness, improving healthcare infrastructure, and ensuring affordable access to diagnostic and treatment services. International collaborations and funding initiatives are crucial in bridging the gap and improving breast cancer outcomes worldwide.[10]

Future directions in research

The future of breast cancer research holds immense promise, with several areas poised for breakthroughs. Liquid biopsy, a minimally invasive technique that detects cancer-related genetic material in blood, is emerging as a potential game-changer for early detection and monitoring treatment response.[11] Additionally, research into the tumor microenvironment and the role of cancer stem cells is shedding light on mechanisms of metastasis and resistance to therapy.[12] Artificial intelligence (AI) and machine learning are also making inroads into breast cancer research.[13] These technologies are being leveraged to enhance diagnostic accuracy, predict treatment responses, and identify novel drug targets. By analyzing vast datasets, AI can uncover patterns and insights that may not be apparent through traditional research methods.[14,15]

Conclusion

Breast cancer research has made significant strides, transforming the landscape of diagnosis, treatment, and survivorship. However, the journey is far from over. Continuous investment in research, global collaboration, and a commitment to equitable healthcare are essential to overcoming the challenges that remain. As we stand on the cusp of new discoveries, the collective efforts of researchers, clinicians, and policymakers will be pivotal in advancing the fight against breast cancer and ultimately improving outcomes for women worldwide.[16]

Despite these advancements, challenges such as disparities in access to screening and treatment persist, particularly in low- and middle-income countries. Addressing these disparities requires a concerted effort to improve healthcare infrastructure, increase awareness, and ensure affordable access to diagnostic and therapeutic services. The future of breast cancer diagnosis is poised for further breakthroughs with the advent of liquid biopsy and the application of artificial intelligence. These technologies promise to enhance early detection, monitor treatment responses, and identify novel therapeutic targets, thereby transforming patient outcomes.[17]

In conclusion, the strides made in breast cancer diagnostics underscore the importance of continuous research and innovation. As we advance, the focus must remain on equitable healthcare and global collaboration to ensure that every woman, regardless of her socioeconomic status, has access to the best possible care. Through these efforts, we move closer to a future where breast cancer is not only treatable but preventable, significantly improving the quality of life for women worldwide.

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Conflicts of interest

The authors declare no conflicts of interest.

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