The Application of CRISPR Technology in Breast Cancer

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Abstract: With the continuous progress of the times and the rapid development of science and technology, CRISPR technology has also undergone the test of time and gradually demonstrated its convenience and professionalism. In the detection of breast cancer (BC), the scientific application of CRISPR technology can significantly enhance the efficiency and quality of detection. This paper focuses on an in-depth exploration of the practical applications of CRISPR technology in breast cancer detection and provides a detailed introduction to the pathological mechanisms of breast cancer. However, the discussion in this paper is limited to the application of CRISPR technology in this specific field; thus, the conclusions and perspectives presented may carry a degree of subjectivity and one-sidedness. Additionally, the technology itself still faces unresolved challenges and inherent limitations. Expanding the application of gene editing technology in BC detection will facilitate earlier medical intervention to improve patient recovery rates and, to some extent, stimulate economic growth. While this research offers valuable empirical references for future studies, certain technical issues remain unresolved. Future investigations should prioritize addressing these technological constraints for refinement.

1 INTRODUCTION

CRISPR technology is widely applied in modern society and holds significant research potential. Currently, there are substantial gaps in the existing research on CRISPR technology. It's a repetitive structure widely distributed in the genomes of bacteria and archaea, providing immunity to prokaryotes during their resistance to phages or other pathogens (Wang et al., 2017). Meanwhile, breast cancer (BC) is one of the most prevalent cancers among women worldwide. In 2018 alone, the global incidence and mortality rates of this cancer among women were $46.3/10^5$ and $13.0/10^5$, respectively, with an upward trend (Bray et al., 2018). It is caused by the uncontrolled proliferation of epithelial cells in the breast. Integrating CRISPR technology into the BC detection process would facilitate early cancer detection and timely intervention. Currently, most existing treatment options involve drug therapy or surgery, which can have significant impacts on the body, potentially causing side effects such as vomiting and weakened immunity (Trayes et al., 2021). Optimizing detection methods and enabling early intervention could reduce mortality risks, alleviate societal pressures to some extent, and strengthen social stability. CRISPR enables the editing of target genes, allowing for the deletion or addition of specific DNA segments. It also offers advantages such as simplicity of operation, low cost, and high efficiency (Wang et al., 2017). Its application in BC detection and treatment could theoretically enable direct or indirect modification of pathogenic genes at the DNA level, with additional benefits such as low error rates and high efficiency, allowing for precise detection, deletion, or replacement of pathogenic genes. This process could also be extended to other related diseases, providing valuable references.

This paper aims to summarize the applications of CRISPR technology in BC detection and treatment, including an introduction to CRISPR technology, its usage, and its principles, while also highlighting its limitations. It reviews current applications and looks to the future, providing reference value and support for researchers in related fields, thereby potentially improving the cure rates of other diseases to some extent.

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2 PATHOGENESIS OF BC

The onset of BC is directly related to estradiol and estrone. Early menarche, late menopause, infertility and late first childbirth, short breastfeeding time, and estrogen replacement therapy after menopause can prolong the exposure of estrogen in the body and are closely related to the onset of BC. At the same time, genetic factors are also high-risk factors for BC. If there is a history of BC in first-degree relatives, the risk of developing the disease is two to three times that of ordinary people. Gene mutations can also increase the risk of BC. Physical factors such as chest radiotherapy can also cause the occurrence of BC.

2.1 Epidermal Growth Factor Receptor (EGFR)

As people continue to deepen their understanding of the pathogenesis of BC, studies have found that members of the growth factor family such as epidermal growth factor and vascular endothelial growth factor play an important role in the occurrence and metastasis of BC. PGRN, as a member of the growth factor family, has also been confirmed to be abnormally expressed in a variety of epithelial tumors, regulating the occurrence and development of tumors, but there are few reports on the regulatory effect of PGRN on BC. This study found that PGRN was significantly upregulated in BC tissues through immunohistochemistry detection, and was positively correlated with EGFR expression.

This suggests that there may be some association between the two in BC, and the mechanism of PGRN regulating BC may be related to EGFR. EGFR is encoded by the EGFR gene located on chromosome 7. When EGFR binds to ligands such as EGF, EGFR will undergo homodimerization or heterodimerization, and can regulate and transfer the life activities of cells through internal signal transduction pathways, and it is concluded that PGRN is an important conclusion in the occurrence and development of tumors.

In BC-related studies, it was found that PGRN has an effect on tumor cells. Due to excessive production of ligands, upregulation of EGFR transcription levels, EGFR mutations, and EGFR gene amplification, EGFR constitutive activation will lead to excessive cell proliferation (Li, et al., 2020). In BC tissues, the positive expression rate of EGFR is high, especially in triple-negative BC. It is reported that more than 50% of triple-negative BC have high expression, but antibody drugs targeting EGFG have not achieved good results in treating BC patients.

Therefore, studying the molecular mechanism of EGFR function in BC may provide direction for the future clinical treatment of BC. PGRN is a secretory cell growth factor with multiple functions. PGRN is involved in a variety of physiological and pathological processes, including cell proliferation, angiogenesis, and damage repair (Li, et al., 2020). According to studies in tumor cells, reducing the level of PGRN mRNA can greatly slow down tumor cell proliferation, and also plays a major role in the growth of triple-negative BC cells. When PGRN is reduced, the proliferation and cloning ability of BC cells decreases, and the volume of the formed tumor is about 90% smaller than that of the parent tumor cells of PGRN (Mahmoudian, et al., 2022).

2.2 Human Epidermal Growth Factor Receptor 2 (HER2)

One of the more extensively researched BC genes to date, HER2 was independently identified by three research teams in the 1980s. The HER2 gene is a key target for the selection of targeted therapy medications for BC in addition to being a prognostic indication for clinical treatment monitoring. Serum HER2 may be an independent prognostic factor that influences the therapeutic outcome. It is linked to the lymph node status and tumor burden HER2 of BC patients.

Compared with the low-level TIL group, the high-level group of invasive BC was HER2-positive, with a high proportion of round/elliptical, smooth edges, and ring enhancement on MRI, while the proportion of peritumoral edema was low. JIA observed breast ductal carcinoma in situ and DCIS with micro invasiveness and proposed that high levels of BCTIL are associated with HER2 overexpression. Another study (Zhou, et al., 2021) showed that BC with high TIL levels is more likely to show characteristics such as round/elliptical and smooth edges. Studies have shown that high TIL BC has a high proportion of uneven enhancement, and enhancement pattern and ADC value are independent predictors of BCTIL levels. Some researchers believe that BCTIL levels are not related to peritumoral edema (P=0.16), which may be related to mechanical obstruction of the local lymphatic vascular system leading to fluid retention or leakage in the peritumoral space. ADC value can quantitatively evaluate the diffusion of water molecules in the tumor; T1 value can potentially quantitatively evaluate the intrinsic characteristics of

the tumor. The average ADC value of BC with high TIL level is higher than that of those with low TIL. ÇELEBI et al. found that BCTIL level was positively correlated with its ADC value; Guo Yi et al. believed that the average ADC value of BC was weakly negatively correlated with its Ki-67 expression level (Park, et al., 2021).

2.3 Editing Principle of CRISPR-Ca9

A single guide RNA and a Cas protein make up the ribonucleoprotein complex that makes up the CRISPR/Cas system. By using complementary guide RNAs to activate Cas enzymes, the system starts a trans-cutting process that breaks down random single-stranded DNA in a targeted manner. A CRISPR array with only a few hundred palindromes makes up the entire CRISPR/Cas locus. 30–40 bp spacers are used to separate these exact repeat sequences. The operon contains clusters of Cas genes, which encode effector and adaptability modules as well as a few auxiliary genes. The mechanism of action of CRISPR/Cas includes the following three stages:

a. Adaptation stage: incorporation of the spacer into the host genome, that is, capturing and integrating a piece of foreign virus or plasmid DNA into the CRISPR sequence array as a new spacer sequence;

b. Expression stage: pre-CRISPR RNA transcription and processing, that is, the transcribed crRNA combines with the auxiliary RNA to form a mature gRNA, ready to participate in subsequent DNA recognition and cutting;

c. Interference stage: the target genetic element is destroyed by the crRNA-Cas protein effector complex due to the semi-independent evolution of different modules.

The classification of CRISPR/Cas systems is a complex issue. Existing CRISPR/Cas system classifications use a variety of criteria, including characteristic Cas genes, organization of Cas operons, and phylogeny of conserved Cas proteins. The generally accepted view is to divide all CRISPR/Cas systems into two categories, 6 types, and 33 subtypes. Class I systems are types I, III, and IV, with multi-subunit effector complexes composed of several Cas proteins, while in Class II, they are types II, V, and VI, and the effector is a single large multi-domain protein. These subtypes differ in subtle differences in site organization and usually encode subtype-specific Cas proteins. Type I, II, and V systems recognize and cut DNA, type VI targets RNA, and type III cuts DNA and RNA. Class II is widely used in basic and translational medicine research because it is easier to operate as a single nuclease protein structure.

3 APPLICATION PROGRESS

3.1 Diagnosis

There are many ways to detect BC. Doctors usually use molybdenum target, nuclear magnetic resonance and manual examination to diagnose BC.

Molybdenum target, the full name of it is mammography, is an imaging technology widely used in the diagnosis of breast diseases (Chen, 2025), which is mostly used to diagnose carcinoma in situ and early cancer. Its principle is that breast molybdenum target examination is an examination method that uses X-ray to penetrate breast tissue for imaging and displays abnormalities through tissue density differences (Chen, 2025). Observe whether there are clustered calcifications in this way, and then confirm the diagnosis.

In addition, there is magnetic resonance imaging (MRI). Nuclear magnetic resonance technology uses the spin motion characteristics of non-zero magnetic moment atomic nuclei in a magnetic field for imaging. The phase change of atomic nucleus movement is analyzed to realize the measurement of three-dimensional velocity in space (Zhang, et al., 2025).

In addition, according to the doctor's manual examination, since BC is a solid tumor and the breast is exposed on the body surface rather than viscera, it is easy to find the mass through the manual examination if there is a lesion, so as to find the lesion.

In addition to accurate detection methods, B-ultrasound is the main means of normal checkup. Its advantages are low cost, little damage to the body and short operation time. However, it can not confirm the diagnosis of BC, and further examination is needed if abnormalities are found.

3.2 Treatment

3.2.1 Conventional Therapy and Its Disadvantages

The conventional therapy of BC refers to surgery, chemotherapy and radiotherapy. Surgery is difficult to remove all lesions in the body of patients with advanced stage, and it is unable to treat metastatic

cancer or even accelerate the spread of cancer, causing great loss to the body. Chemotherapy can be used to eliminate systemic cancer, but at the same time of eliminating cancer cells, some normal cells will also be eliminated, which may lead to hair loss, nausea, decreased immunity, decreased anticoagulant function, anemia and so on. Besides, it brings greater consumption of the body. Radiotherapy can only be used to eliminate local lesions, but it is also easy to bombard DNA, causing secondary cancer. The above three conventional therapies have certain drawbacks, so now there are many new therapies to replace or assist

3.2.2 CAR-T Immunotherapy

Car-t immunotherapy aims to activate the immune system to attack cancer cells. Car-t consists of chimeric antigen receptor (car) and T cells. The principle is to extract T cells from patients' blood and combine them with car protein through gene editing, so that it can accurately target and recognize cancer cells and distinguish normal cells, and induce the immune system to attack cancer cells. At the same time, car-t still has many side effects, such as the high activation and proliferation of car-t cells stimulated by tumor associated antigens, the interaction with surrounding cells to activate the immune system at the same time of killing tumor cells, and the positive feedback cycle of cytokines produced induces a series of cells to release cytokines to strengthen the inflammatory response, leading to the occurrence of CRS （ Cytokine Release Syndrome ）. Car-t immunotherapy has bipolarity in clinical practice, which shows that patients who are sensitive to immunotherapy will get much better, and tumors will be gradually eliminated, but many patients have no response to this medical method.

3.2.3 Monoclonal Antibodies (mAbs)

MAb drugs, such as trastuzumab, are mAbs against HER-2, that is, highly homogeneous antibodies produced by a single B cell clone that only target a specific epitope. By occupying the site, it effectively prevents human epidermal growth factor from attaching to HER-2 and reduces the overexpression, thereby inhibiting the growth of cancer cells (Liu, 2025).

BC is a solid tumor. According to the different conditions of patients, the combined treatment of surgery, chemotherapy, radiotherapy and immunotherapy is usually adopted. Therefore, targeted assistance of gene editing technology is crucial. This therapy aims to reduce the occurrence of cancer metastasis and recurrence, which can be effectively matched according to the situation of different patients, so as to minimize damage and maximize treatment.

4 CONCLUSION

This paper delves into the practical applications of CRISPR technology in breast cancer (BC) detection and provides a detailed explanation of its underlying mechanisms. Additionally, the study analyzes the pathological mechanisms of BC and highlights the potential of CRISPR technology in BC detection through research. The findings suggest that expanding the application of CRISPR technology in BC detection could significantly reduce the mortality risk for breast cancer patients and alleviate the economic burden associated with treatment, thereby offering greater security for families, promoting social harmony and stability, and driving economic development.

The experience gained from applying CRISPR technology in BC detection not only provides valuable insights for genetic testing in other related fields but also offers innovative solutions to common challenges in genetic detection. However, the current application of CRISPR technology still faces certain limitations. For instance, the precision of detection needs further improvement, and the operational procedures remain relatively complex, issues that require additional research and refinement. Moreover, while CRISPR technology is primarily utilized in detection, its efficacy in actual therapeutic applications is still limited, which somewhat restricts its broader potential. Nevertheless, with continuous technological advancements and new scientific breakthroughs, it is anticipated that these challenges will be effectively addressed in the near future, paving the way for broader clinical applications of CRISPR technology.

AUTHORS CONTRIBUTION

All the authors contributed equally and their names were listed in alphabetical order.

REFERENCES

Bray, F., Ferlay, J., Soerjomataram, I., et al. 2018. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA: A Cancer Journal for Clinicians, 68(6), 394-424.

Chen, L. 2025. Breast mammography: An imaging tool for accurate diagnosis of breast diseases. Health Reading, 2025(2), 24.

Li, X., Zhao, L., Chen, C., et al. 2020. Can EGFR be a therapeutic target in breast cancer? Biochimica et Biophysica Acta (BBA) - Reviews on Cancer, 1877(5), 188789.

Liu, L. 2025. Effect of combined treatment of HER2-positive breast cancer with pertuzumab and trastuzumab and its impact on CA125, CEA expression and quality of life of patients. Practical Journal of Cancer, 40(2), 255-257.

Park, N. J., Jeong, J. Y., Park, J. Y., et al. 2021. Peritumoral edema in breast cancer at preoperative MRI: An interpretative study with histopathological review toward understanding tumor microenvironment. Scientific Reports, 11(1), 12992.

Purrahman, D., Mahmoudian-Sani, M. R., Saki, N., et al. 2022. Involvement of progranulin (PGRN) in the pathogenesis and prognosis of breast cancer. Cytokine, 151, 155803.

Trayes, K. P., & Cokenakes, S. E. H. 2021. Breast Cancer Treatment. American Family Physician, 104(2), 171–178.

Wang, H. Y., Yuan, T. W., Wang, C. N., & Xiong, Y. 2017. Analysis of the development trend of genome editing technology represented by CRISPR technology. Competitive Intelligence, 13(3), 10.

Zhang, X., Zhao, H. F., Zhao, X. B., et al. 2025. Research progress of multimodal MRI in the evaluation of hypoxia in breast cancer microenvironment. Magnetic Resonance Imaging, 16(1), 210-215.

Zhou, C., Huang, Y., Wu, J., et al. 2021. A narrative review of multiple mechanisms of progranulin in cancer: A potential target for anti-cancer therapy. Translational Cancer Research, 10(9), 4207-4216.