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A COMPREHENSIVE STUDY ON BREAST CANCER: DIAGNOSIS, TREATMENT, AND PREVENTION

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ABSTRACT

Breast cancer remains a major global health concern and is the most frequently diagnosed cancer among women. It originates from the uncontrolled proliferation of epithelial cells in the breast ducts or lobules and is influenced by multiple factors such as genetics, hormonal imbalance, age, lifestyle, and environmental exposure. Early diagnosis plays a vital role in reducing mortality and improving survival rates. Diagnostic tools like mammography, ultrasound, MRI, and biopsy are essential for detecting cancer at an early stage, while molecular testing for biomarkers such as estrogen receptor (ER), progesterone receptor (PR), and HER2 aids in selecting appropriate therapy.

Treatment strategies depend on the type and stage of cancer and include surgery, chemotherapy, radiation therapy, hormonal therapy, and targeted therapy. Recent innovations such as immunotherapy, gene therapy, and nanotechnology-based drug delivery systems are showing promising results in enhancing treatment efficacy and reducing side effects. Prevention focuses on lifestyle modification, maintaining a healthy diet, regular physical activity, genetic screening for high-risk individuals, and creating public awareness about early detection and self-examination.

This review provides a comprehensive overview of breast cancer, emphasizing the importance of timely diagnosis, advanced therapeutic approaches, and preventive measures. It highlights the need for continuous research, patient education, and improved healthcare strategies to minimize disease burden and enhance the quality of life of affected individuals.

KEYWORDS: *Breast cancer, Diagnosis, Treatment, Prevention, Hormonal therapy, Targeted therapy, Immunotherapy, Early detection, Risk factors, Nanotechnology*

1.INTRODUCTION

Breast cancer is a major global health problem and the most frequently diagnosed malignancy among women, representing a leading cause of cancer-related deaths worldwide. It develops due to the abnormal and uncontrolled growth of epithelial cells lining the ducts or lobules of the breast. Although it primarily affects women, men can also develop breast cancer, albeit at a much lower rate. The disease burden is particularly high in developing countries, where lack of awareness, limited screening facilities, and late-stage diagnosis contribute to higher mortality rates. The exact cause of breast cancer is multifactorial, involving a combination of genetic, hormonal, environmental, and lifestyle-related factors. Mutations in genes such as BRCA1, BRCA2, and TP53 significantly increase susceptibility to breast cancer. Hormonal imbalances, early menarche, late menopause, nulliparity, obesity, exposure to radiation, alcohol consumption, and physical inactivity have also been identified as contributing risk factors. Understanding these underlying causes is essential for developing preventive strategies and personalized treatment approaches.

The pathogenesis of breast cancer involves complex interactions between genetic mutations and hormonal signaling pathways that lead to uncontrolled cell proliferation, loss of apoptosis, angiogenesis, and metastasis. Based on histopathology, breast cancer is classified into several types, including ductal carcinoma in situ (DCIS), invasive ductal carcinoma (IDC), and invasive lobular carcinoma (ILC). The stage and grade of the tumor play crucial roles in determining prognosis and treatment planning.Early detection remains the cornerstone for successful management. Diagnostic techniques such as mammography, ultrasound, MRI, and biopsy enable accurate identification and staging of tumors. In recent years, molecular profiling using biomarkers like estrogen receptor (ER), progesterone receptor (PR), and human epidermal growth factor receptor 2 (HER2) has revolutionized treatment selection, allowing for more targeted and individualized therapies.Treatment options for breast cancer have evolved significantly, ranging from surgical interventions and radiation therapy to systemic treatments such as chemotherapy, hormonal therapy, targeted therapy, and immunotherapy.

The integration of these modalities, combined with supportive care, aims to achieve tumor control, prevent recurrence, and enhance the patient's quality of life. Preventive measures, including lifestyle modification, genetic counseling for high-risk individuals, and widespread awareness programs, have proven effective in lowering disease incidence and mortality.Despite remarkable advances in diagnosis and treatment, several challenges remain, such as drug resistance, high treatment costs, and disparities in healthcare accessibility. Continuous research focusing on precision medicine, nanotechnology, and gene-based therapies holds great promise for the future management of breast cancer.This comprehensive review aims to provide an in-depth overview of breast cancer,

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highlighting its epidemiology, etiology, diagnostic methods, treatment modalities, preventive strategies, and emerging innovations. It emphasizes the importance of early detection, patient education, and multidisciplinary approaches to reduce the global burden of this life-threatening disease.

2.ANATOMY AND PHYSIOLOGY OF BREAST CANCER

The human breast is a specialized accessory gland of the female reproductive system that plays an important role in milk production (lactation) and nourishment of infants. Anatomically, each breast lies on the anterior chest wall, extending vertically from the second to the sixth ribs and horizontally from the sternum to the mid-axillary line. It is composed of glandular, fibrous (connective), and adipose tissues supported by suspensory ligaments of Cooper, which help maintain the breast's structural shape.

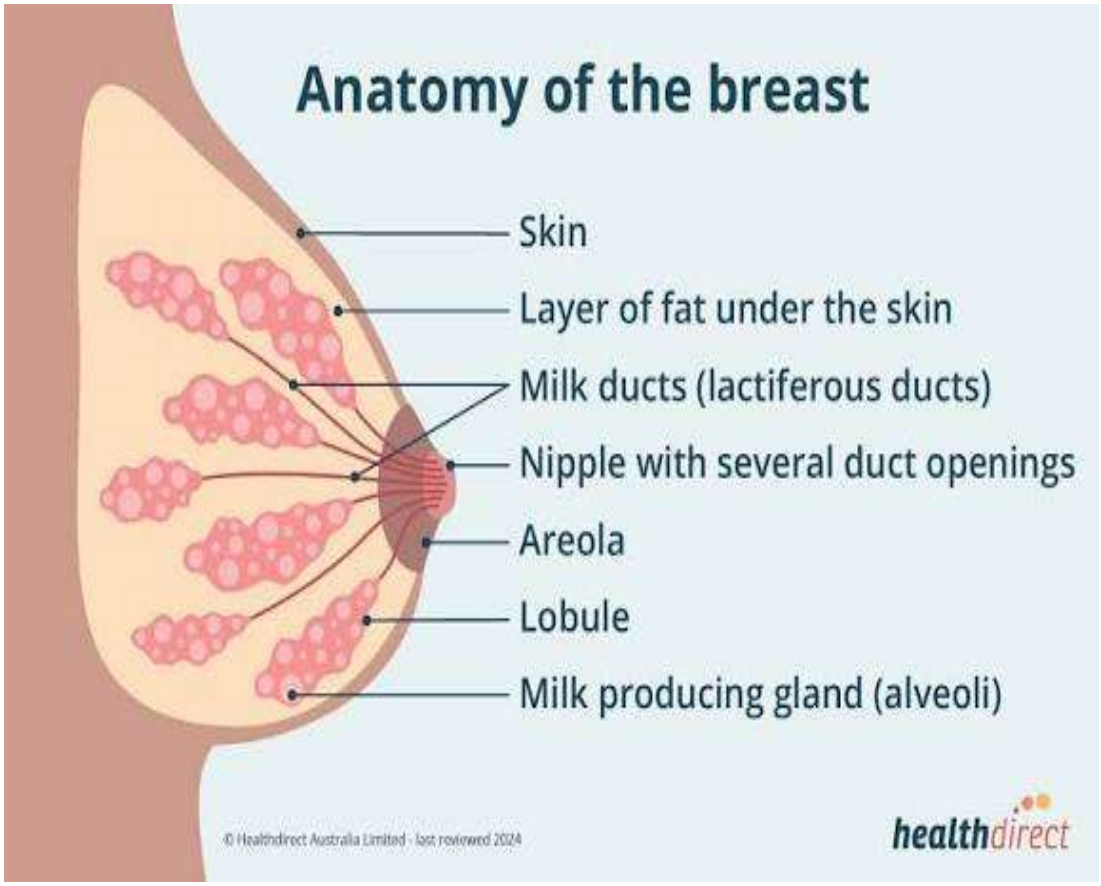


Fig.no 01 Anatomy of the Breast

2.1 ANATOMY

The breast is divided into 15–20 lobes, each of which contains smaller units called lobules. These lobules consist of clusters of alveoli (acini) lined with secretory epithelial cells responsible for milk production. The alveoli drain into lactiferous ducts, which merge to form larger ducts that open onto the nipple through lactiferous sinuses. The nipple is surrounded by a pigmented area known as the areola, which contains sebaceous glands that secrete lubricating substances to protect the nipple during breastfeeding. The blood supply to the breast is provided mainly by the internal mammary (thoracic) artery and the lateral thoracic artery, while venous drainage occurs through the axillary and internal thoracic veins. The lymphatic system is extensive, with about 75% of lymph drainage passing to the axillary lymph nodes, an important pathway for the spread (metastasis) of breast cancer cells. The nerve supply comes from branches of the intercostal nerves, which regulate sensation in the skin and nipple.

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Table no. 1 Breast Cancer

STAGE	TUMOR	LYMPH NODE	SPREADING
Stage 0	Very small inside the glands	No cancer	Inside breast area not outside
Stage 1	Less than 2 cm	No cancer	Inside breast area not outside
Stage 2	2-5 cm	Affected by cancer	Inside breast area not outside
Stage 3	More than 5 cm	Cancer has reached the muscles & skin	Inside breast area not outside
Stage 4	Any size	Affected by cancer	spread outside the breast area to any body part

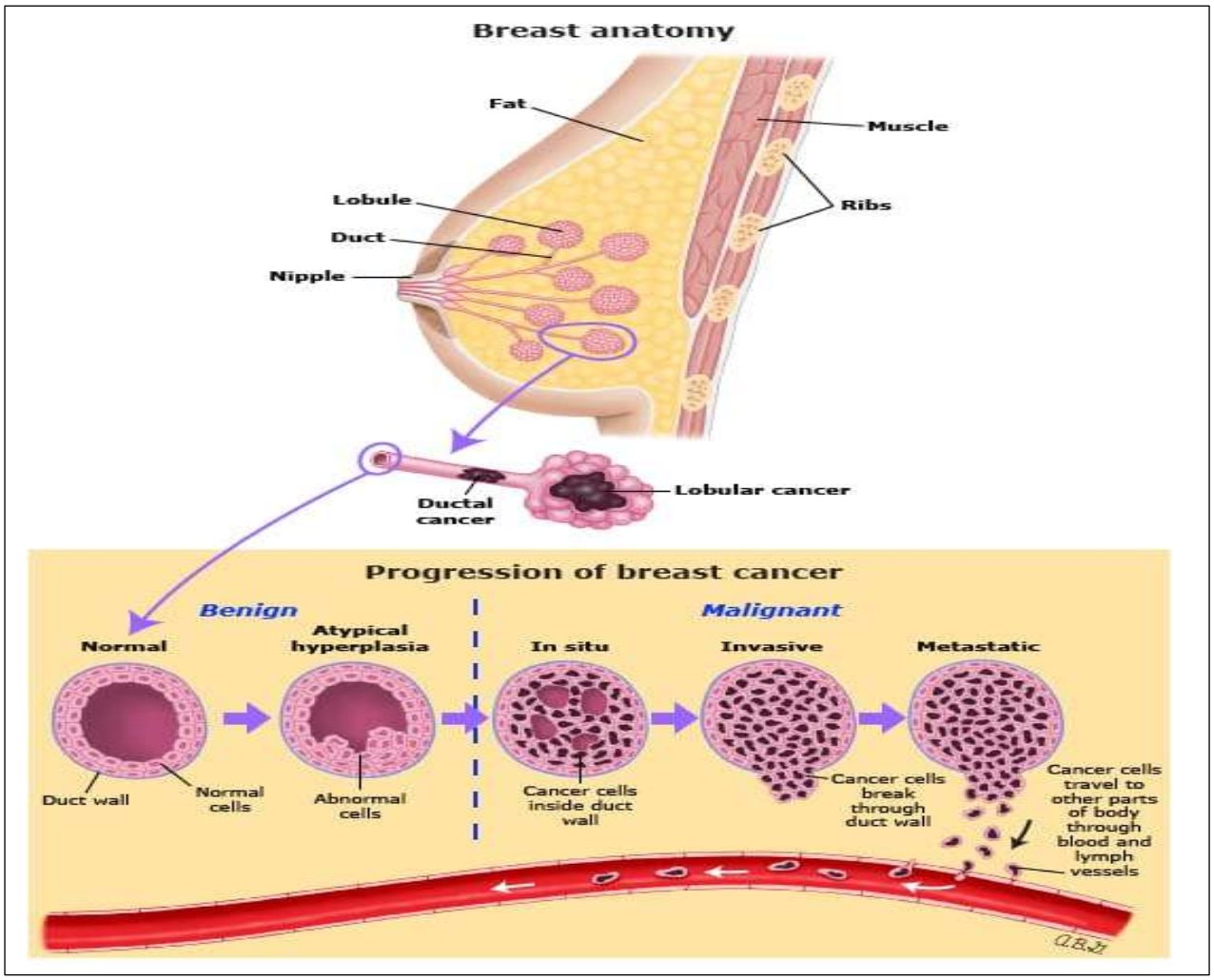


Fig.No. 02 Progression of Breast Cancer

2.2 PHYSIOLOGY

The physiological function of the breast is primarily related to lactation, which is under hormonal control.

- Estrogen stimulates the growth and development of the ductal system.
- Progesterone promotes the formation of glandular tissue and lobular-alveolar structures.
- Prolactin, secreted by the anterior pituitary gland, triggers milk production, while oxytocin released from the posterior pituitary causes milk ejection during suckling.
- Other hormones such as growth hormone, cortisol, and insulin also support breast development and metabolic functions.

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3. ETIOLOGY AND RISK FACTOR

The etiology and risk factors of breast cancer are multifactorial and involve a complex interaction of genetic, hormonal, environmental, and lifestyle influences that cause abnormal and uncontrolled growth of breast cells. Breast cancer develops when normal breast cells undergo genetic mutations that alter their growth-regulating mechanisms, allowing them to divide uncontrollably and invade surrounding tissues. Among the genetic factors, mutations in the BRCA1 and BRCA2 genes are the most significant, as they are responsible for hereditary breast and ovarian cancer syndromes.

These genes normally help repair damaged DNA, but when mutated, they allow harmful changes to accumulate, leading to cancer formation. Women carrying BRCA1 or BRCA2 mutations have up to an 80% lifetime risk of developing breast cancer compared to about 10–12% in the general population. Other genes such as TP53, PTEN, CHEK2, and PALB2 are also linked to hereditary breast cancer. A family history of breast or ovarian cancer, especially in first-degree relatives, significantly raises the risk, indicating a strong genetic component. Hormonal factors also play a major role. Estrogen and progesterone are natural hormones that regulate the growth and function of breast tissue, but prolonged exposure to high levels of these hormones can increase the risk of malignancy.

Women who experience early menarche (before 12 years) or late menopause (after 55 years) are exposed to estrogen for a longer duration, which stimulates cell proliferation in the breast ducts and lobules. Similarly, women who have their first pregnancy after age 30 or never give birth (nulliparous women) have a higher risk because pregnancy and breastfeeding induce changes in breast cells that make them more mature and less likely to become cancerous.



Fig.No 03 Etiology &Risk Factor

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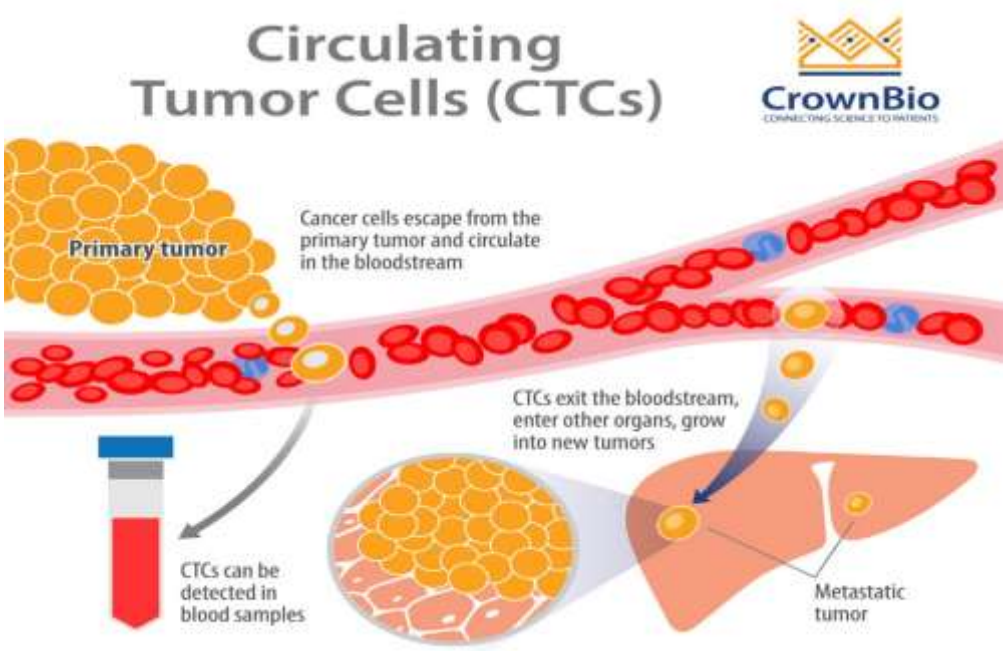


Fig.no 04 Circulating Tumor Cell

4. SIGN AND SYMPTOMS

The signs and symptoms of breast cancer vary among individuals and depend on the type, stage, and location of the tumor. In its earliest stages, breast cancer often causes no noticeable symptoms, which is why regular screening and self-examination are essential for early detection. The most common and often first symptom noticed by women is a painless lump or thickening in the breast tissue or underarm area. This lump may feel hard, irregular in shape, and different from the surrounding tissue. It usually persists even after the menstrual cycle, distinguishing it from temporary hormonal breast changes. Sometimes, the lump may be tender or painful, but most cancerous lumps are painless and firm. The size of the lump may vary, and in some cases, it may not be easily palpable, especially in women with dense breast tissue, highlighting the importance of mammography and imaging techniques in early diagnosis.

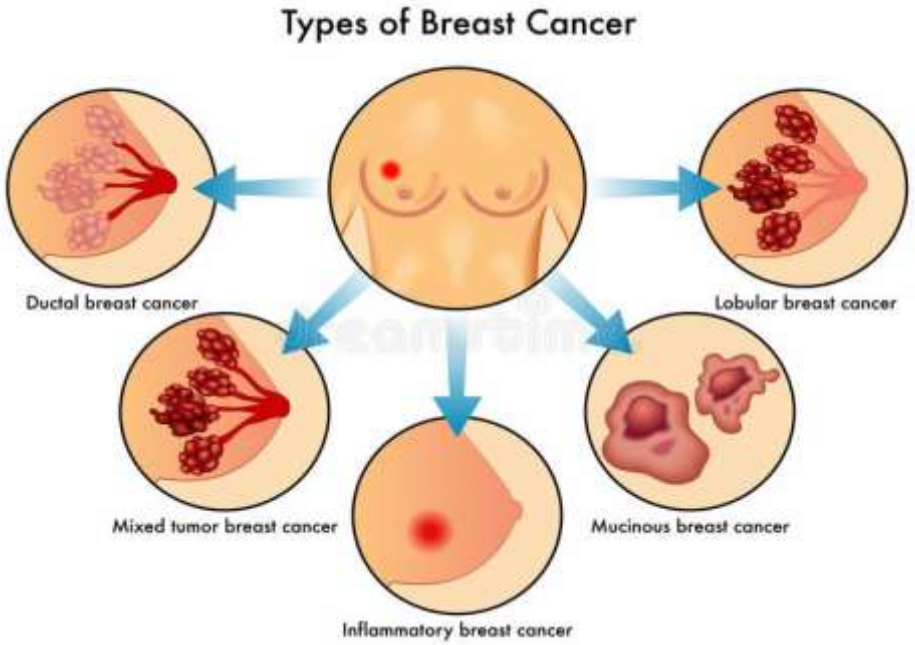


Fig no 05 Type Of Breast Cancer

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Some breast cancers, such as inflammatory breast cancer, present differently from typical cases. This aggressive form of cancer causes rapid swelling, redness, and warmth in the breast, often without a distinct lump. The skin may become tight, shiny, and thickened, with visible dilated veins on the surface. The breast may feel heavy and painful, and these changes can occur quickly, often within weeks or months. Because inflammatory breast cancer mimics infection, it is frequently misdiagnosed as mastitis, delaying proper treatment.

In men, although breast cancer is rare, similar symptoms can occur, including a painless lump beneath the nipple, nipple retraction, or bloody discharge. Men may also experience ulceration or scaling of the nipple area. Due to lack of awareness, male breast cancer is often detected at a later stage, making early recognition crucial.

It is important to note that not all breast changes indicate cancer. Many benign conditions—such as fibroadenomas, cysts, infections, or hormonal changes—can cause lumps or tenderness. However, any new or persistent change in the breast should be investigated through clinical examination, imaging (mammography, ultrasound), and biopsy to rule out malignancy. Regular breast self-examination (BSE), ideally performed monthly a few days after the menstrual cycle ends, helps women become familiar with the normal look and feel of their breasts and detect any unusual changes early.

In postmenopausal women, who are at higher risk, clinical breast examination by a healthcare professional and screening mammograms are recommended as part of routine preventive care. The American Cancer Society and World Health Organization emphasize early detection through awareness of symptoms and timely screening, which significantly improves survival rates. Early-stage breast cancer, when detected before it spreads, is highly treatable with surgery, radiation, and targeted therapies.

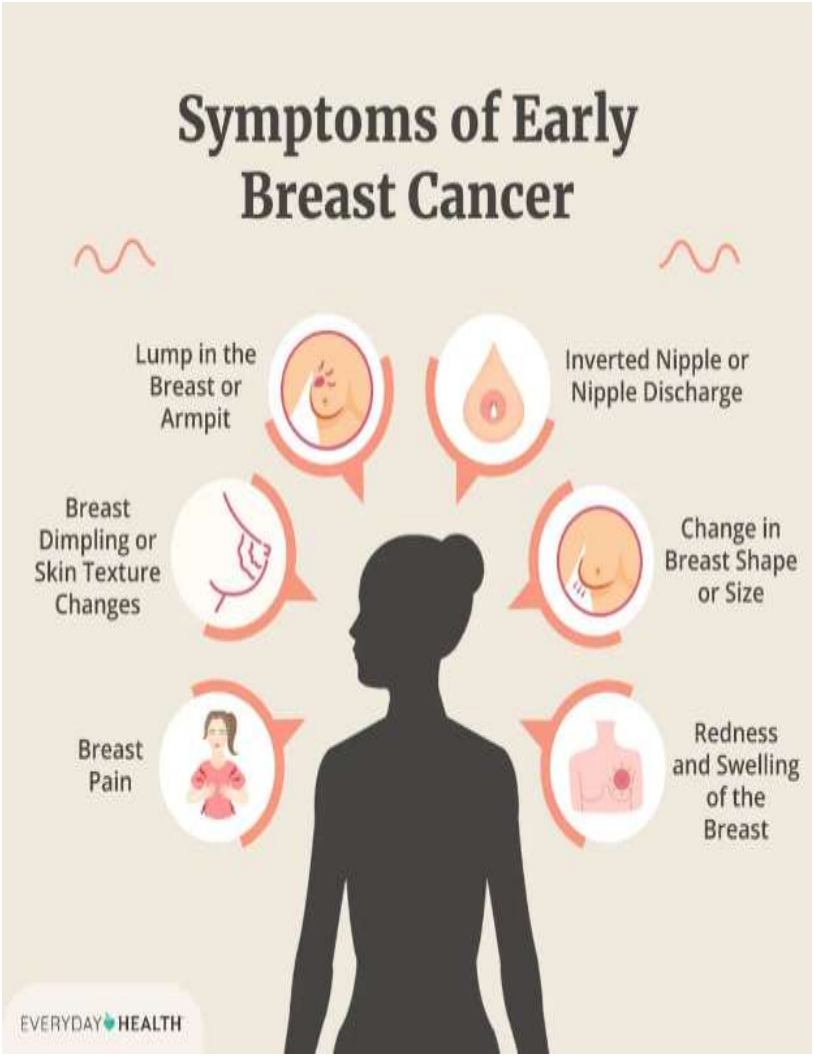


Fig.No 06 Symptoms of breast cancer

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5. DIAGNOSIS

Early and accurate diagnosis is critical in the management of breast cancer, as it allows timely treatment and significantly improves prognosis. Breast cancer diagnosis involves a combination of clinical evaluation, imaging techniques, laboratory tests, and pathological examination.

5.1. Clinical Examination

- History Taking: Evaluation of patient history including family history, reproductive factors, hormonal therapy, lifestyle habits, and previous breast disease.
- Physical Examination: Thorough palpation of both breasts and axillary, supraclavicular, and cervical lymph nodes to detect lumps, skin changes, or nipple abnormalities.
- Breast Self-Examination (BSE): Encouraged monthly for early detection of lumps or changes, especially in women over 20 years.

5.2. Imaging Techniques

Imaging plays a crucial role in detecting and characterizing breast lesions.

Mammography

- Considered the gold standard for breast cancer screening.
- Can detect microcalcifications, small masses, and early tumors before they are palpable.
- Recommended annually for women aged 40 and above.

Ultrasound

- Differentiates between solid and cystic masses.
- Useful in younger women with dense breast tissue where mammography may be less effective.
- Magnetic Resonance Imaging (MRI):
- Highly sensitive for detecting multifocal, multicentric, or bilateral breast cancers.
- Often used in high-risk patients (e.g., BRCA mutation carriers) or preoperative staging.

Digital Breast Tomosynthesis (DBT)

- Advanced 3D mammography technique improving detection accuracy and reducing false positives.

5.3. Biopsy Methods

- Definitive diagnosis of breast cancer requires histopathological confirmation.
- Fine Needle Aspiration Cytology (FNAC):
- Minimally invasive, used for initial evaluation of palpable lumps.
- Provides cytological assessment but may not provide complete architectural details.

Core Needle Biopsy (CNB)

- Larger tissue samples allow detailed histopathological evaluation and receptor status analysis.
- Preferred over FNAC for accurate diagnosis.

Excisional Biopsy

- Complete removal of a suspicious lump when other biopsy methods are inconclusive.

5.4. Laboratory and Molecular Tests

- Hormone Receptor Testing: Estrogen receptor (ER) and progesterone receptor (PR) status determine suitability for hormonal therapy.
- HER2/neu Testing: Overexpression indicates eligibility for targeted therapy (e.g., trastuzumab).
- Ki-67 Proliferation Index: Evaluates tumor growth rate.
- Genetic Testing: BRCA1, BRCA2, and other gene mutation analysis for high-risk individuals.

5.5. Staging and Classification

After diagnosis, accurate staging is performed using the TNM system (Tumor size, Node involvement, Metastasis). Staging helps guide treatment and predict prognosis:

- Stage 0: Carcinoma in situ (non-invasive)
- Stage I–II: Early invasive cancers, limited to the breast or nearby lymph nodes
- Stage III: Locally advanced cancer with extensive lymph node involvement
- Stage IV: Metastatic cancer spreading to distant organs

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5.6. Emerging Diagnostic Methods

- Molecular Imaging: PET/CT and molecular breast imaging for detecting metastasis.
- Liquid Biopsy: Detection of circulating tumor DNA (ctDNA) or circulating tumor cells (CTCs) for early diagnosis and monitoring therapy response.
- Artificial Intelligence (AI) in Imaging: AI-assisted mammography and MRI interpretation improve detection accuracy and reduce human error.

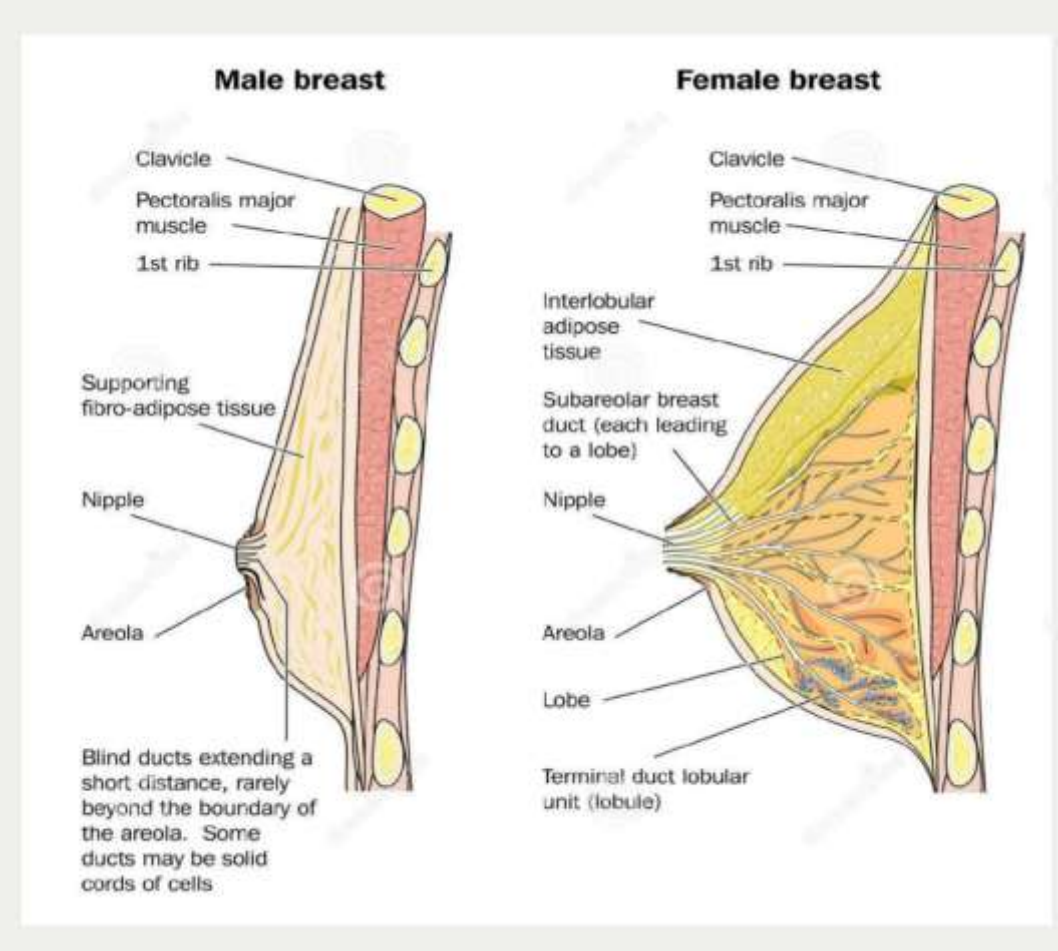


Fig.no 07 Difference Male & Female

6. PATIENT HISTORY

Mrs. Alpana Pathak, a 38-year-old woman from **Ranchi, India**, was diagnosed in 2017 with Stage IV metastatic breast cancer, with the disease already spreading to her lungs and brain. She initially presented with a breast lump, fatigue, headaches, and breathlessness. Diagnosis was confirmed through mammography, biopsy, CT, MRI, and genetic testing (NGS). Over the years, she underwent multiple rounds of chemotherapy, radiotherapy, and targeted therapies, including NGS-guided personalized **treatment in 2024–2025.** During her treatment, she faced severe complications, including infection requiring ventilator support, but responded well to advanced therapies. By 2025, she achieved remission, regained normal activity, and her case highlights that even advanced breast cancer can have a positive outcome with modern, personalized treatment strategies.

Table No.02 Patient History

CATEGORY	DETAILS
Age	38 years
Gender	Female
Location	Ranchi ,india
Diagnosis year	2017
Type of cancer	Stage IV *Metastatic Breast Cancer
Histological type	Invasive Ductal Carcinoma (suspected)
Site of metastasis	Lungs and Brain
Symptoms at presentation	Breast lump, fatigue, weight loss, difficulty breathing (due to lung spread), headaches (due to brain metastasis)

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Stage at diagnosis	Stage IV (advanced and metastatic)
Diagnostic method	Mammography, Biopsy, CT Scan, MRI, Blood Tests, and Next-Generation Sequencing (NGS)
Treatment given (2017-2024)	Chemotherapy* (multiple cycles) Radiotherapy* (for breast and brain lesions) Targeted Therapy* (based on genetic testing) Hormonal Therapy* (as per receptor status) Surgical Interventions* for local control
Additional interventions	Ventilator support during severe infection (late 2024); advanced ICU care
Recent treatment (2024-2025)	Personalized Targeted Therapy* guided *Next-Generation Sequencing (NGS)* of blood
Response to treatment	Significant improvement after targeted therapy; able to come off ventilator and regain normal activity
Current health status (2025)	Stable, active, and living a normal life; in remission phase under medical supervision
Key learning points	Early diagnosis is crucial - Even advanced breast cancer can respond with modern therapy - NGS and targeted treatments improve survival - Family support and mental health care are vital

6.1 List of drug

1. Hormonal (Endocrine) Therapy

Used for hormone receptor-positive breast cancer (ER/PR+).

- Tamoxifen – Selective estrogen receptor modulator (SERM), used in pre- and post-menopausal women.
- Toremifene – Similar to tamoxifen.
- Fulvestrant – Selective estrogen receptor degrader (SERD).
- Aromatase inhibitors (AIs) – Block estrogen production, mainly in postmenopausal women:
  - Anastrozole
  - Letrozole
  - Exemestane

2. **Chemotherapy**

Used for triple-negative breast cancer, high-risk tumors, or metastatic cases.

- Anthracyclines:
  - Doxorubicin
  - Epirubicin
- Taxanes:
  - Paclitaxel
  - Docetaxel
- Alkylating agents:
  - Cyclophosphamide
  - Antimetabolites:
  - 5-Fluorouracil (5-FU)
  - Capecitabine
- Platinum agents (for TNBC or BRCA mutations):
  - Carboplatin
  - Cisplatin

3. Targeted Therapy

Used for HER2-positive or specific genetic breast cancers.

- HER2 inhibitors:
  - Trastuzumab
  - Pertuzumab
  - Ado-trastuzumab emtansine (T-DM1)
  - Trastuzumab deruxtecan

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- CDK4/6 inhibitors (ER+ metastatic):
  - Palbociclib
  - Ribociclib
  - Abemaciclib

- PARP inhibitors (BRCA-mutated cancers):
  - Olaparib
  - Talazoparib

- PI3K inhibitors:
  - Alpelisib (for PIK3CA-mutated cancers)

4. Immunotherapy

- Pembrolizumab – Used for PD-L1 positive triple-negative breast cancer.

5. Supportive/Adjuvant Drugs

Used to reduce side effects or enhance treatment tolerance:

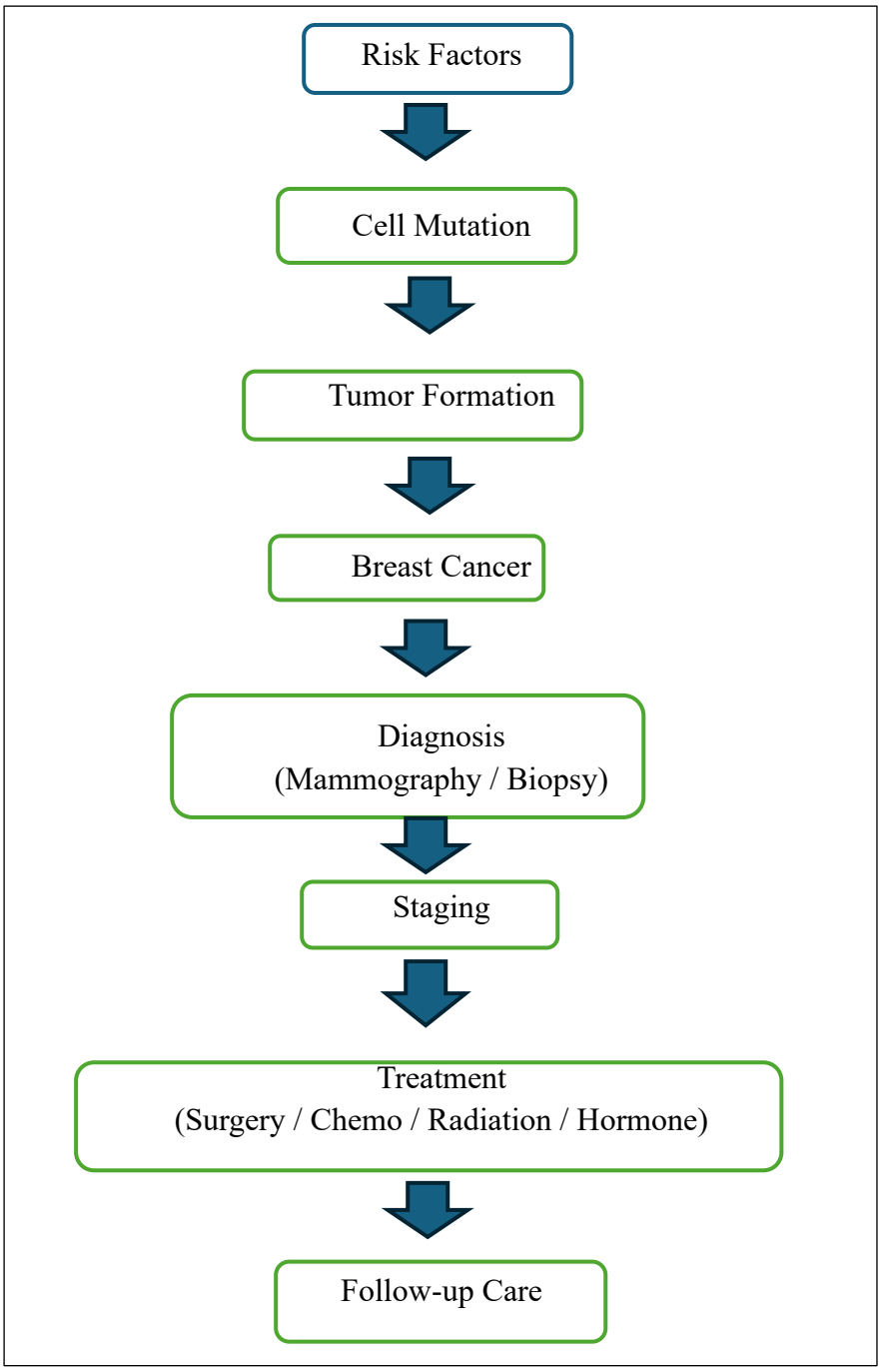
- Bone-modifying agents: Zoledronic acid, Denosumab
- Anti-nausea: Ondansetron, Aprepitant
- Growth factors: Filgrastim (to boost WBC counts during chemo)

7. TREATMENT OF APPROACHES

The signs and symptoms of breast cancer vary among individuals and depend on the type, stage, and location of the tumor. In its earliest stages, breast cancer often causes no noticeable symptoms, which is why regular screening and self-examination are essential for early detection. The most common and often first symptom noticed by women is a painless lump or thickening in the breast tissue or underarm area. This lump may feel hard, irregular in shape, and different from the surrounding tissue. It usually persists even after the menstrual cycle, distinguishing it from temporary hormonal breast changes. Sometimes, the lump may be tender or painful, but most cancerous lumps are painless and firm. The size of the lump may vary, and in some cases, it may not be easily palpable, especially in women with dense breast tissue, highlighting the importance of mammography and imaging techniques in early diagnosis.

Another important sign of breast cancer is a change in the size, shape, or appearance of the breast. One breast may appear larger, swollen, or have a different contour compared to the other. The affected breast may show visible skin changes such as dimpling, puckering, or thickening, giving it an appearance similar to an orange peel, known as “peau d’orange.” This occurs due to obstruction of lymphatic drainage by cancer cells, leading to localized fluid accumulation. The skin over the breast may also become red, scaly, or irritated, resembling an infection or inflammation, which sometimes leads to misdiagnosis as mastitis, especially in younger or lactating women.Changes in the nipple are also common warning signs. The nipple may become inverted (pulled inward) or show a deviation in direction, which was not previously present. Persistent nipple pain, itching, or burning sensations can occur, along with crusting or scaling of the nipple and areola, especially in cases of Paget’s disease of the breast, a rare form of cancer involving the nipple ducts. Another significant symptom is nipple discharge, which may be bloody, clear, or yellowish, and can occur without squeezing. While nipple discharge is not always due to cancer, any spontaneous or bloody discharge should be promptly evaluated.

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8. RECENT ADVANCES IN BREAST CANCER

Recent years have seen significant progress in breast cancer diagnosis, treatment, and management, improving survival rates and quality of life for patients. Key advances include:

7.1. Precision and Personalized Medicine

- Tumor genetic profiling allows treatments to be tailored to the patient's molecular tumor type.
- Helps predict treatment response and minimize unnecessary therapies.

7.2. Targeted Therapy

- Drugs designed to target specific cancer cell proteins or pathways (e.g., HER2 inhibitors like trastuzumab).
- Reduces damage to normal cells compared to conventional chemotherapy.

7.3. Immunotherapy

- Immune checkpoint inhibitors (e.g., PD-1/PD-L1 blockers) enhance the immune system's ability to attack cancer cells.

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- Particularly promising in triple-negative breast cancer, which lacks hormonal or HER2 targets.

7.4. Nanotechnology-Based Drug Delivery

- Nanoparticles deliver chemotherapy drugs directly to tumor cells, increasing efficacy and reducing systemic toxicity.
- Can improve penetration in dense breast tissue or hard-to-reach tumors.

7.5. Liquid Biopsy

- Detects circulating tumor DNA (ctDNA) or tumor cells (CTCs) in blood.
- Enables early detection, monitoring of recurrence, and assessment of treatment response without invasive procedures.

7.6. Advanced Imaging and AI

- 3D mammography, MRI, and PET-CT enhance early detection and precise tumor localization.
- Artificial Intelligence (AI) assists radiologists in detecting subtle lesions and predicting tumor behavior.

7.7. Gene Therapy and Epigenetic Approaches

- Targeting mutated genes or epigenetic changes to halt tumor progression.
- Experimental therapies aim to reactivate tumor suppressor genes or silence oncogenes.

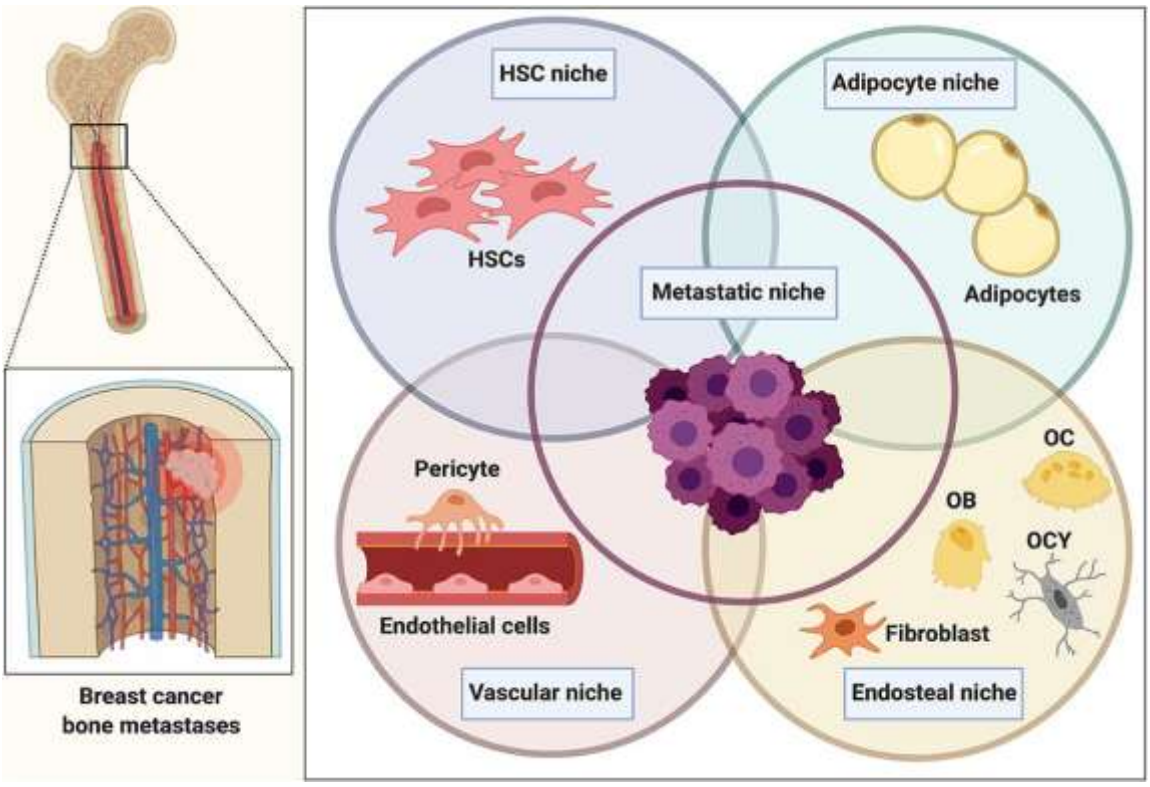


Fig.no.08 Breast Cancer Bone Metastases

9. FUTURE PROSPECTS IN BREAST CANCER

The future of breast cancer management is focused on precision, personalization, and early intervention, aiming to improve survival rates, reduce side effects, and enhance quality of life. Advances in genomic, proteomic, and molecular profiling allow clinicians to tailor treatments to individual tumor characteristics, identify novel biomarkers for early detection, and predict therapeutic responses. Next-generation targeted therapies are being developed to inhibit specific oncogenic pathways and overcome drug resistance, while combination regimens promise higher efficacy with fewer adverse effects.

Immunotherapy, including immune checkpoint inhibitors, CAR-T cell therapy, and experimental cancer vaccines, holds significant potential for aggressive or treatment-resistant tumors. Liquid biopsy technologies enable non-invasive detection of circulating tumor DNA (ctDNA) and circulating tumor cells (CTCs), allowing real-time monitoring of disease progression, early relapse detection, and personalized adjustment of therapy. Innovations in nanotechnology-based drug delivery allow precise targeting of tumor cells, minimizing toxicity to healthy tissue, while artificial intelligence (AI) and digital health platforms enhance imaging accuracy, treatment planning, and patient monitoring.

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Additionally, gene-editing technologies like CRISPR/Cas9 and epigenetic therapies offer the potential to correct genetic mutations, reactivate tumor suppressor genes, and silence oncogenes, paving the way for preventive and curative strategies. Integrating these approaches, future breast cancer care envisions a multidisciplinary, patient-specific model that combines early detection, precision treatment, immune modulation, and advanced monitoring to transform breast cancer into a manageable, preventable, and increasingly curable disease.

10. CONCLUSION

Although breast cancer is a major cause of morbidity and mortality in women, and thus is of understandable concern to life underwriters, basic understanding of the disease often allows for aggressive underwriting I some cases. Women with DCIS and LCIS who have been correctly managed should still be eligible for optimistic ratings, whereas underwriting women with cumulative risk factors described in this treatise, as well as unfavorable pathology and especially the presence of axillary metastases, calls for ever increasing caution.Of particular note to underwriting departments is the newer reports of the discriminating power of measurements of cyclin Eand analysis of the levels of expression ofthousands of genes simultaneously with the use of DNA microarray technology in identifying women with stage I and II breast cancers with both much better, and those with much worse, prognoses than is now available with knowledge of estrogen-receptor status and the presence or absence of lymph node metastases.

In the section Risk Factors for Development of Breast Cancer, we have reviewed the data available at the time of this writing on the controversial role of hormone replacement therapy (HRT) in post-menopausal women. Although some controversial points remain, there does appear to be mounting evidence that HRT that includes both estrogen and progestin does entail risks that need to be considered in underwriting decisions. Perhaps the most significant finding in ourreview was that 70% to 75% of women with invasive breast cancer actually die of something other than their breast malignancy. Although there are certainly red flags that should raise serious concern in underwriting these women, there are many ‘‘breast cancer survivors’’ who are just that: they apparently have survived their disease. But only a firm understanding of all of the issues described in this review will allow for the selection of these insurable cases.

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