# "Exploring Nanotechnology Applications in Breast Cancer."

By

Jannatul Ferdaus Tonima

22346042

Md. Fardin Khan

22346051

A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Pharmacy (B. Pharm.) to the School of Pharmacy

BRAC University

December, 2025

## Declaration

It is hereby declared that

1. The thesis submitted is our own original work while completing a degree at Brac University.

2. The thesis does not contain material previously published or written by a third party, except

where this is appropriately cited through full and accurate referencing.

3. The thesis does not contain material which has been accepted, or submitted, for
any other degree or diploma at a university or other institution.

4. I have acknowledged all main sources of help.

## Signatures of the Student

---

**Jannatul Ferdaus Tonima**

22346042

---

**Md. Fardin Khan**

22346051

## Approval

The thesis titled "Exploring Nanotechnology Applications in Breast Cancer" was submitted by Jannatul Ferdaus Tonima **(**22346042), Md. Fardin Khan (22346051) has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of Pharmacy.

## Supervised By:

Dr. Sabrina Sharmin

Associate Professor

School of Pharmacy, BRAC University

## Approved By :

Dr. Raushanara Akter
Professor & Acting chairperson
School of Pharmacy,
BRAC University

A. F.M. Yusuf Haider, PhD Acting Dean,
School of Pharmacy
Professor,
Department of Mathematics and Natural Science
BRAC University

## Ethics Statement

There is no involvement of animal or human trials in this project.

## Abstract

This thesis shows and gives us an idea about the knowledge of disease biology with developments in nanoscale advances to investigate the many uses of nanotechnology in breast cancer. The study opens with a review of the pathophysiology of breast cancer, highlighting the molecular and genetic abnormalities that drive tumor development and progression. It also categorizes the main forms and clinical phases of breast cancer, providing the biological and medical background required to assess new Nano-technological treatments. Building on this framework, the thesis investigates how nanotechnology is transforming the identification, diagnosis, and management of breast cancer. It also assesses the broader advantages of nanotechnology, such as enhanced selectivity and treatment efficacy, alongside its disadvantages, including potential toxicity and production complexities. Key challenges and limitations that range from biocompatibility concerns to regulatory hurdles are critically discussed.

## Keywords:

Pathogenesis, nanoparticles, liposomes, quantum Dots, gold nanoparticles, pathophysiology

## Dedication

***"Dedicated to my parents"***

**Acknowledgment**

First and foremost, we would like to express our gratitude to the Almighty for his endless gifts, which have been given to us in an effort to provide us with the strength and determination to complete this project.

It is our genuine pleasure to offer our heartfelt appreciation to our academic supervisor, Dr. Sabrina Sharmin (Associate professor at Brac University's, Department of Pharmacy), for her invaluable guidance and encouragement during this project. Through the course of our education and project writing, she was a true source of advice and support for me. We are quite grateful to her for her valuable comments and ideas during my study, which helped so much in completing project work in a timely manner.

## Table of contents

# Chapter 1

## Introduction

Cancer is a broad group of diseases caused by alterations to genes and epigenetics, which disable regular cell division, differentiation, and apoptosis. The compromised cells grow uncontrollably, forming tumors, invade adjacent tissues, and may metastasize to other organs. Cancer is biologically complex because it has multiple interacting hallmarks, like sustained proliferative signaling, evasion of growth suppressors, resistance to cell death, angiogenesis, and immune escape (Hanahan & Weinberg, 2011).

Cancer remains a heavy burden for public health worldwide. According to recent large-scale estimates, mortality rates have been consistently high over the past five years. The Global Burden of Disease Cancer Collaborators estimate that about 10 million people died from cancer globally in 2019. In 2020, deaths from cancer remained near 10.0 million (Sung et al., 2021). Based on the most recent GLOBOCAN-based estimates for 2022, it was estimated that there were 9.7 million deaths (Bray et al., 2024). New estimates from GBD studies indicate that the number of deaths will increase again due to population growth and aging to about 10.4 million in 2023 (GBD 2023 Cancer Collaborators, 2025). These numbers mean that the annual deaths from cancer worldwide have remained at approximately the same

levels since 2019, roughly between 9.7 and 10.4 million. This further indicates how crucial it is to enhance prevention, early detection, and new treatments.

The main contributor to this problem is breast cancer. It primarily arises from epithelial cells lining the breast ducts or lobules and exhibits biological heterogeneity, with subtypes based on receptor status (ER, PR, HER2) and molecular profile. Nowadays, this is the most common type of cancer in women all over the world and one of the main cancer burdens in terms of deaths among women (Sung et al., 2021). Mortality rates have remained high but stable for the last five years. In the year 2020, breast cancer in women was responsible for the deaths of approximately 685,000 people worldwide (Sung et al., 2021). More recent estimates from GLOBOCAN 2022 put deaths at around 670,000 globally, a sign that the disease continues to be lethal despite advances in the treatment modalities developed so far (Kim et al., 2025). These data indicate that breast cancer forms a significant component of annual global cancer mortality and continues to be one of the hotspots for therapeutic innovation, including nanotechnology-based interventions.

## 1.1 Aims of the Project

The aim of this paper is to look into the prospects of nanotechnology as an emerging, transformative approach for the management of breast cancer. It seeks to understand how nanoparticle-based systems can be integrated into modern oncology to improve the overall pathway of care-from early detection and accurate diagnosis to more effective and safer treatment. By reviewing current scientific evidence, this project aims at highlighting the benefits of nanomedicine compared to conventional strategies, its clinical relevance within different subtypes of breast cancer, as well as identifying issues for future consideration that will be critical before wider medical adoption can be achieved. The ultimate goal of this project is to contribute to a better understanding of how nanotechnology might result in an improvement in survival and quality of life for breast cancer patients.

## 1.2 Objective of this review

- To provide a brief scientific overview of cancer and breast cancer, including current global mortality rates.
- To explain the principles of nanotechnology and how nanoparticles are used to cure cancer.
- To evaluate the application of nanotechnology in breast cancer detection, diagnosis, and treatment.
- To investigate the primary nanoparticle platforms' modes of action in the therapy of breast cancer.
- To assess the current limitations of nanomedicine and its potential to improve quality of life and breast cancer survival.

## Chapter 2

## Methodology

The development of nanotechnology-based treatments for breast cancer involves several key steps. These steps are synthesis of nanoparticles, drug loading , functionalization, in vitro and in vivo testing, and clinical evaluation.

The first step for this aim is the synthesis of nanoparticles. Different techniques, such as nanoprecipitation, solvent evaporation, and emulsion polymerization, have been employed in the fabrication of nanoparticles with desired characteristics like size, shape, and surface properties. These materials can be made from lipids, polymers, or metals. Their design usually depends on how they will be used, such as for drug delivery, imaging, or combined therapies.

These engineered nanoparticles are designed to carry therapeutic agents, including chemotherapy drugs, gene therapies, and antibodies. This ensures proper drug encapsulation or attachment to the nanoparticle to enhance its stability, improve its solubility, and provide for controlled release at the site of action.

Functionalization is the modification of the surface of the nanoparticles toward targeting specific markers of breast cancer; this involves attaching ligands-antibodies or peptides-that attach to receptors overexpressed on the surface of tumor

cells. This targeting ensures that the therapy is delivered directly to the tumor, minimizing side effects on healthy tissues (Peer et al., 2007).

After functionalization, in vitro tests are conducted using breast cancer cell lines to examine cytotoxicity, the drug release profile, and cellular uptake of the nanoparticles. All of these tests will give an idea about the effective interaction and delivery of therapeutic agents by nanoparticles with cancerous cells (Blanco et al., 2015).

After that, in vivo testing of nanoparticles is done in animal models to find out their pharmacokinetics, biodistribution, and therapeutic efficiency (Jain & Stylianopoulos, 2010). For this purpose, many imaging techniques such as MRI or fluorescence imaging are employed in tracing the accumulation of nanoparticles in tumors and for appraising the therapeutic outcome.

# Chapter 3

# Mechanism of Action

## 3.1 Pathogenesis of Breast Cancer

The disease of breast cancer is underlaid by complex processes at the genetic, molecular, and environmental levels. Under normal conditions, in the breast, growth, differentiation, and apoptosis of the epithelium are tightly regulated. In breast cancer, this process is interrupted, which favors uncontrolled cellular division and growth. Most human breast cancers develop as a result of mutations in oncogenes, tumor suppressor genes, and/or mechanisms involved in DNA repair.

The major molecular pathways of breast cancer pathogenesis are:

**Hormone Receptor Signaling (Estrogen and Progesterone Receptors)**: Most breast cancers are estrogen receptor-positive, meaning that tumor growth is induced by the steroid hormone estrogen. This subtype of breast cancer depends on estrogen signaling for the proliferation of cells and thus remains very sensitive to endocrine therapy. However, this type of treatment also faces potential resistance through changes in mutations that alter the activity of hormone receptors or through cross-talk with other signaling pathways, including HER2 (Sood et al.2025)

**HER2 (Human Epidermal Growth Factor Receptor 2)**: HER2 is a receptor whose amplification and/or overexpression has been seen in nearly 20% of all breast cancers. This receptor promotes the proliferation and rapid growth of tumors by

activating the downstream signaling pathways, such as the mitogen-activated protein kinase and PI3K. Targeted therapies, such as trastuzumab, commercially known as Herceptin, have revolutionized the prognosis of HER2-positive breast cancers (Hassan et al. 2022).

**Genomic Instability:** Tumor cells are, in general, burdened with high genomic instability due to mutations in critical tumor suppressor genes such as TP53, BRCA1, and BRCA2. These interfere with DNA repair capability in the cell and also provoke further mutations; cancer proceeds, and the tumor becomes resistant to conventional therapies (Mitragotri & Anderson, 2025).

In general, the breast cancer tumor microenvironment has a strong influence on the pathogenesis and disease development of the tumor. Indeed, inflammation, angiogenesis, and immune response represent some processes that allow the surrounding tissues to be invaded by the breast cancer cells, thus allowing their metastasis to distant organs. (Sood et al., 2025)

### 3.2 Types of Breast Cancer

Various types of breast cancer can be differentiated depending on the histology and molecular features. Classification is necessary because it defines the clinical approach toward diagnosis, treatment, and prognosis.

**Histological Types**

**1. Ductal Carcinoma In Situ**: DCIS is a diagnosis of non-invasive carcinoma confined to the milk ducts. The malignant cells have not invaded the surrounding tissues; therefore, DCIS is generally treatable. It is often considered a precursor to the invasive ductal carcinoma if left untreated (Bertucci et al., 2024).

**2. Invasive Ductal Carcinoma (IDC)**: IDC is the most common kind of invasive breast cancer. It first begins in the milk ducts of the breast, then invades surrounding tissue. It accounts for 70–80% of all invasive breast cancers. IDC may metastasize to other parts of the body; this constitutes the major cause of mortality (Mitragotri & Anderson, 2025.).

**3. Invasive Lobular Carcinoma:** ILC originates within the milk-producing lobules and is considered the second most frequent type of invasive breast cancer. Usually, ILCs are more difficult to visualize on mammograms and usually present as a diffused thickening of the breast rather than a well-defined lump. (Sood et al., 2025)

**4. Inflammatory Breast Cancer (IBC):** IBC is a rare, aggressive type of breast cancer that results in redness, swelling, and inflammation of the breast. Because of

the disease's sudden growth, and because there's no distinct lump, IBC is generally diagnosed at a point when the disease is in its advanced stages.

**5. Triple-Negative Breast Cancer (TNBC):** TNBC lacks expression of ER, PR, and HER2. This generally makes the cancer more aggressive and unresponsive to the use of either hormone therapies or those targeting HER2. TNBC tends to be higher in the young female population and among African-American females (Mitragotri & Anderson, 2025).

**6. HER2-positive breast cancer**: This subtype of cancer is driven by overexpression/amplification of the HER2 gene and leads to very aggressive tumor growth. These are more responsive to treatments with the use of targeted therapies such as trastuzumab (Herceptin) or pertuzumab, according to the work of Bertucci et al. (2024).

**Molecular Subtypes**

Another classification involves the division of breast cancer based on molecular characteristics represented through gene expression profiles. These offer a personalized approach to treatment.

**Luminal A**: The cancers of Luminal A subtypes are ER-positive, HER2-negative, and of low proliferation rate-low Ki-67. Usually, these cancers are slow-growing and carry the best prognosis. They also respond to endocrine therapies quite well.

**Luminal B**: Similar to Luminal A, cancers within the category of Luminal B are

ER-positive; however, they have a higher proliferation rate and can sometimes be HER2-positive. They are generally more aggressive compared to Luminal A tumors and may require both endocrine therapy and chemotherapy administration in combination (Bertucci et al., 2024).

**HER2-Enriched:** These are cancers which are HER2-positive but lack both estrogen and progesterone receptors. These cancers tend to be quite aggressive, and treatment for them will involve targeting the HER2 molecule using drugs such as trastuzumab, commercially named Herceptin.

**Triple Negative:** Triple-negative breast cancers lack all three receptors: ER, PR, and HER2. These cancers are often highly aggressive and, consequently, considered to have a poor prognosis; they can be treated only by chemotherapy or newer therapies like immunotherapy (Mitragotri & Anderson, 2025).

## 3.3 Stages of Breast Cancer

Disease staging is very important in establishing a prognosis and applying the appropriate treatment. The most widely used classification system is TNM, which is based on tumor size, lymph node involvement, and the extent to which cancer has spread to other parts of the body.

**Phase grouping**

**Stage 0:** Non-invasive cancer includes conditions such as DCIS or LCIS, wherein the malignant cells remain confined to the ducts or lobules and have not yet invaded the tissue lining it. Although these conditions, DCIS and LCIS, are precursors to invasive cancers, the conditions are highly treatable with surgery combined with radiotherapy (Mitragotri & Anderson, 2025).

**Stage I:** In this stage, the tumor is small ≤2 cm. There is no spread to nearby lymph nodes. Surgery is generally the standard therapy for Stage I, including possible radiation and endocrine or targeted therapies for persons whose tumors are hormone-receptor-positive or HER2-positive, respectively (Bertucci et al., 2024).

**Stage II:** The tumor is between 2 to 5 cm in size, or the cancer has spread to a few lymph nodes nearby; treatment approaches involve surgery which may be followed by chemotherapy, radiation, and endocrine therapy (Sood et al., 2025).

**Stage III:** This is the stage at which tumor sizes are bigger than 5 cm or have spread significantly to lymph nodes and other tissues of the surrounding area. Treatment at

this stage may involve neoadjuvant chemotherapy for reduction in tumor size, followed by surgery, radiation, and further systemic therapies (Hassan et al., 2022).

**Stage IV:** Metastatic breast cancer is defined as the dissemination of the tumor to distant organs such as the lungs, liver, bones, or brain. During this stage, the cancer is no longer curable, and treatments are mostly palliative, focusing on prolonging survival and alleviating symptoms. Possible treatments that can be used at this stage include chemotherapy, targeted therapy, immunotherapy, and hormone therapy (Bertucci et al., 2024).

# Chapter 4

## Nanotechnology

Nanotechnology refers to the manipulation of matter on a nanometer scale. In addition, it contains other unique properties, such as enlarged surface area, reactivity, and solubility. Recently, it has found several applications, from medicine, especially in cancer treatment. Nanoparticles are tiny particles with dimensions between 1 and 100 nanometers that can be engineered to interact with biological systems in unique ways to facilitate precise delivery of drugs, imaging, and treatment (Blanco et al., 2015).

Nanotechnology plays an important role in anticancer therapy through designing nanoparticles, targeted therapy, diagnostics, and imaging techniques, and the development of new drug delivery systems (Peer et al., 2007). In such cases, these nanoparticles can be functionalized with targeting ligands that attach to certain receptors on cancerous cells so that therapeutic agents reach tumor tissue with little or no exposure to healthy tissues.

## 4.1 Nanotechnology in Breast Cancer Detection

The chances of survival and successful treatment for breast cancer patients are higher in cases of early detection. The classic techniques for the detection of cancer are mammography, ultrasound, and biopsy, though all these methods bear the burdens of limitations in sensitivity, specificity, and capability for the identification of small or early-stage tumors (Davis, Chen, & Shin, 2008). Nanotechnology can offer promising solutions that improve the sensitivity and specificity of breast cancer detection by enhancing imaging techniques, molecular biomarkers, and precision in tumor cell detection.

### Nanosensors and Molecular Biomarkers

The use of nanosensors represents one of the upcoming technologies with regard to diagnosis related to breast cancer. These sensors are capable of detecting certain biomarkers within the breast cancer cells or tissues, which generally occur at very low concentrations. Because of their highly sensitive nature, nanoparticles can provide the potential for tumor marker detection far in advance, often before the tumor can be clinically identified (Bobo, Robinson, Islam, & Thurecht, 2016).

**Gold Nanoparticles:** AuNPs are one of the most studied nanomaterials for the detection of cancer. These nanoparticles can be functionalized with ligands,

antibodies, or peptides that selectively bind to tumor markers such as HER2, estrogen receptors, or CA15-3 (Cho, Wang, Nie, Chen, & Shin, 2008). Thus, gold nanoparticles act like highly sensitive biosensors that, owing to their ability to bind with these markers, can detect low levels of cancer markers in blood or tissue samples.

**Quantum Dots:** Quantum dots are semiconductor nanoparticles exhibiting unique optical properties, including fluorescence, which are used in the identification of breast cancer. Conjugation with cancer-specific antibodies allows QDs to perform fluorescent imaging in which the identification of tumor cells can be done with high specificity (Kairdolf, Smith, Stokes, Wang, & Nie, 2013).Their applications to in vivo imaging, now under development, offer real-time monitoring of tumors during surgery or chemotherapy.

**Magnetic Nanoparticles:** The magnetic nanoparticles also hold great promise for the detection of breast cancer. In MRI, SPIONs are used to enhance contrast with a view to increasing the visibility of tumors, particularly in the early stages of the disease . Many ligands specifically targeting tumor cells can be attached to SPIONs, thereby enhancing their sensitivity and specificity in detecting breast cancer (Wu, Wu, Yu, Jiang, & Kim, 2015).

## Surface-Enhanced Raman Scattering (SERS)

Another promising detection method involves the use of metallic nanoparticles, especially gold or silver, to enhance the Raman scattering signal of cancer biomarkers through a technique called surface-enhanced Raman scattering (Lane, Qian, & Nie, 2015). This technique is explored in the non-invasive early detection of human breast cancer. Nanoparticles conjugated with specific biomarkers associated with this cancer will permit the detection of such biomarkers in blood or saliva by SERS. Due to the high sensitivity of SERS, even single molecules can be detected; therefore, SERS is a powerful technique for the early diagnosis of cancer (Lane, Qian, & Nie, 2015).

## 4.2 Nanotechnology in Breast Cancer Diagnosis

Upon the diagnosis of breast cancer, its type, stage, and grade need to be ascertained. Nanotechnology provides for more sensitive, more accurate, and less invasive diagnostic modalities. Nanoparticles are employed not only in detecting cancer but also in evaluating its molecular traits to accommodate a treatment approach and offer better personalized care.

### Early-Stage Detection and Screening

Mammography, while the standard technique for the screening of breast cancer, very often does not reveal early-stage cancer, especially in women with dense breast tissue. Nanotechnology offers a chance at earlier and more accurate detection by means of novel screening methods .

**Mammography with nanoparticles:** There are some recent approaches to mammography by incorporating newly developed nanoparticle-based contrast agents for the increased detection of small tumors.Such agents would improve the contrast between normal and tumoral tissues, enabling the detection of lesions that could not be readily visualized by means of a standard mammogram. For example, SPIONs or liposomes, nanoparticles targeting specific receptors on tumor cells,

which enhance resolution and specificity of mammographic images (Mura, Nicolas, & Couvreur, 2013).

**Circulating Tumor Cells (CTCs)**: Another very promising application of nanotechnology in the diagnosis of breast cancer includes the detection of CTCs in blood. The CTCs are defined as those cells of a tumor that have broken off from a primary tumor and circulate in the bloodstream, giving rise to metastasis. The capture and analysis of CTCs at extremely low concentrations have been possible through nanotechnology (Rosenblum, Joshi, Tao, Karp, & Peer, 2018). For example, gold nanoparticles functionalized with antibodies selectively bind to CTCs, thus enabling their isolation and characterization.

## Nanoparticle-Assisted Biopsy

For years, traditional biopsy methods have been invasive; most take a great deal of time and sometimes yield inconclusive results. However, nanotechnology assisted engineers in developing less invasive biopsy alternatives. Nanoparticles coated with specific biomarkers can be administered in the body, which actively target and bind to tumor cells (Bobo et al., 2016). After attachment to the tumor cells, the nanoparticles are easily retrieved through a minimally invasive procedure, such as fine needle aspiration. This process, sometimes referred to as "liquid biopsy," is less

intrusive and constitutes a more efficient way to diagnose breast cancer and monitor disease progression.

## Molecular Diagnostics

Molecular diagnosis entails the analysis of the genetic and molecular composition of tumor cells to identify mutations or other markers that may affect treatment. Nanotechnology plays a vital role in molecular diagnostics, enabling the detection of genetic alterations such as mutations, gene expression levels, and epigenetic modifications.

**Nanoparticles for DNA/RNA Detection:** Nanotechnology has also entered the realm of detecting genetic mutations or changes in gene expression associated with breast cancer. The nanoparticles can be functionalized with DNA or RNA probes which bind selectively to specific gene sequences or transcripts, hence permitting detection of genetic mutations typical in some subtypes of breast cancer, such as HER2 amplification or BRCA1/2 mutations (Cho et al., 2008). This approach has provided critical information for personalized treatment strategies.

**Nanomaterial-based biosensors:** Currently, nanomaterials like carbon nanotubes and graphene are in development for use as biosensors in the detection of the genetic material associated with breast cancer. The sensors that come forth from this will

thus be highly sensitive in the detection of low levels of DNA, RNA, and proteins which are indicative of the disease (Lane et al., 2015).

## 4.3 Nanotechnology in Breast Cancer Treatment

Treatment strategies for breast cancer have improved significantly in recent years, partly due to advances in nanotechnology. Nanoparticles may be utilized to carry chemotherapeutic agents, immunotherapies, and gene therapies directly to the tumor site, decreasing adverse side effects and enhancing the overall efficacy of the treatment (Wang et al., 2012). Nanotechnology also has a role in overcoming drug resistance and improving the response to treatment.

### Nanoparticle-Based Drug Delivery

Traditional chemotherapy often involves the administration of highly toxic drugs systemically, which may affect tumor and healthy cells alike. The consequences include hair loss, nausea, and organ toxicity (Venditto & Szoka, 2013). Nanotechnology enabled the engineering of drug delivery systems that would specifically target the cells that cause breast cancer, limiting toxicity and improving the therapeutic effects of the drug.

**Liposomes and Polymeric Nanoparticles:** Liposomes and polymeric nanoparticles are some of the most studied nanomaterials in drug delivery. Such nanoparticles are more capable of loading chemotherapy drugs such as paclitaxel, doxorubicin, or cisplatin and releasing them at the tumor site. Functionalization of such

nanoparticles with targeting ligands ensures that the drug is released preferentially at the site of the tumor with lesser side effects (Venditto & Szoka, 2013). A well-known example of this is Doxil; this is a liposomal formulation of doxorubicin, which is an FDA-approved nanocarrier for the treatment of breast cancer.

**Stimulus-Responsive Nanoparticles:** These nanoparticles are designed to release their payload in response to a specific trigger in the tumor microenvironment, such as acidic pH, high temperature, or overexpressed enzymes (Mura et al., 2013). This kind of targeted release greatly improves the efficacy and reduces the side effects. For instance, pH-sensitive nanoparticles may deliver drugs in the acidic environment of tumor cells for better treatment outcomes.

## Nanoparticles for Immunotherapy

More recently, immunotherapy has yielded new and promising approaches to treating breast cancer in cases when traditional chemotherapy and radiation therapy are ineffectual. Nanoparticles may enhance immunotherapy by the targeted delivery of immune checkpoint inhibitors, cancer vaccines, or cytokines to the tumor site .

**Nanoparticles-Based Vaccines:** Nanoparticles can act as delivery systems for tumor antigens, enabling improved immune responses to cancer (Rosenblum et al., 2018). This includes the use of cancer-specific antigens and adjuvants encapsulated in nanoparticles and the stimulation of the immune response against breast cancer

cells. Indeed, clinical trials performed with nanoparticle-based cancer vaccines have demonstrated strong immune responses and an increase in survival rates among patients.

**Immune checkpoint inhibitors:** Immune checkpoint inhibitors targeting the cancer tumors can also be delivered using nanoparticles, including anti-PD-1 and anti-CTLA-4 antibodies (Ferrari, 2005). Such inhibitors impede the immune checkpoint proteins, which enable the cancerous cells to escape immune detection, thereby enhancing the immune system to combat cancer.

# Chapter 05

## Advantages, Disadvantages, Challenges Limitations and Future Perspectives of Nanotechnology in Breast Cancer

## 5.1 Advantages of Nanotechnology in Breast Cancer

Nanoparticles show great potential in drug delivery and are currently used quite a lot for cancer therapy, especially in breast cancer.The advantages of nanoparticles are many and they are extremely stable, have a high rate of encapsulation, but can also envelop drugs which are both hydrophobic and hydrophilic. But at the same time, their dangers are apparent. Tiny nanoparticles for example, it can easily pass through membranes and enter all parts of the body, and have a particularly good affinity to cells. They can cause intrinsic toxicity in normal cells from a number of organs.PLGA (National Institute for Materials Science, Kyoto, Japan) has the advantage of being a biodegradable material; however, its rapid collapse leads to a loss in biological retention time in tissues. So when cancers need to be treated over longer periods of time by administration with drugs or cloned genes, all becomes much less effective. The use of nanotechnology provides innovative paths in which to battle breast cancer. If nanocarriers increase drug solubility and stability, extend the life of a drug in body tissues, and allow it to gather at tumor sites more easily, they have at least three benefits that can make doing difference.It is in the nature of their design that these particles release therapeutic agents specifically at tumor sites

and not elsewhere in the body. This means they can achieve this without hurting normal tissues one bit, as we may compare with the way other drugs are spread around.From the nanoparticle approach: normal tissue toxic effects are minimized and the often serious side effects of conventional chemotherapy are bypassed by this focused method of payload delivery (Cheriyan et al., 2025). To enhance Drug effectiveness and bioavailability, nanocarriers increase drug solubility and stability and prolong the period of time in which a drug remains effective in our body, making it easier for drugs to accumulate on tumor sites. The result is that more therapeutic agents can be concentrated in areas where they are most needed, increasing treatment efficiency.

**Dealing with Treatment Limits-**

(Mugundhan & Mohan, 2024b) Nanomedicine provides answers to the difficulties that traditional breast cancer treatments encounter. These include scarce cellular drug absorption, resistance to drugs surgical, radiotherapeutic and chemotherapeutic approaches. It can also help in the treatment of metastatic breast cancer, which is often more difficult to treat effectively.

**Control and prolonged release of drugs-**

Nanotechnology makes drugs have a controlled and sustained ability to come out, thus raising their therapeutic effectiveness and allowing for the use of multiple drug combination therapies at a time. (Miao et al., 2004). Nikdouz et al. (2022) at the resolution of location-based delivery of drugs to cancer cells, nanoparticles help in distinguishing between harmful and non-cancerous cells. With this strategy, convergent targeting allows for lower toxicities and side effects as opposed to conventional treatments based on an empirical basis. Nanotechnology comes to be viewed as an innovative means of treating breast cancer. In this case, nanoparticles are thought to be able to take medications, inhibitors or genes directly to malignant tissues without harming surrounding normal organs. Recent studies of nanotechnology in breast cancer stress certain virtues, namely enhanced solubility, pharmacokinetics and the potential for targeted distribution and treatment (Cheriyan et al., 2025b). However, advantages are coupled with obstacles to wide, effective clinical application of nanotechnology, particularly controlled, experimental clinical trials.

**Advancement of Immunotherapy-**

Advancement of Immunotherapy Nanoparticles offers a means to augment the immune system's capacity to identify and eliminate cancerous cells through drug delivery. Furthermore, they facilitate the development of more potent cancer vaccines, which activate the immune system's recognition and attack of cancer cells. Nanoparticles can be engineered to preferentially interact with the tumor microenvironment, encompassing blood vessels and immune cells associated with the tumor. Logically, this type of personalized therapy enhances immune responses and boosts the effectiveness of immunotherapies.

**Real-time Monitoring and Liquid Biopsies-**

Non-invasive cancer monitoring in nanotechnology makes it possible to develop "liquid biopsy" methods in which nanoparticles filter cancer-indicators from blood samples. This allows for continuous monitoring of the tumour condition without the use of invasive tissue biopsies. As a result, this method helps clinicians to evaluate the effectiveness of treatment and detect early recurrence of cancer. Nanoparticles can also be designed with certain antibodies to detect circulating tumor DNA or RNA in the blood of women already diagnosed with breast cancer, thus offering a less invasive way to monitor the progress of the disease.

## 5.2 Disadvantages of Nanotechnology in Breast Cancer

**Noxious Nanoparticles-**

Nevertheless, inorganic nanoparticles are burdened with several shortcomings, including their unpredictability. This is because inorganic particles possess a large surface area and may have unanticipated effects on biomolecules. Long-term health and environmental risks are of considerable concern. The movement, metabolism and excretion of inorganic nanomaterials within the body have yet to be fully understood (Cohn et al., 1998). Some studies have found that nanoparticles like gold, silver and iron oxide are toxic both in vitro and in vivo. Inorganic nanocarrier slow disintegration might lead to protracted cytotoxicity. Carbon nanotubes have been implicated in increases of metastasis in breast cancer by recapitulating the sexual toxicity between human and animal substances (Karaosmanoglu et al., 2020).

**Stability and Effectiveness-**

Jittery Liu et al. (2024). Medical nanotechnologies face a number of stability challenges in biological settings. As an example, indentations and capture by biological molecules may affect their therapeutic effectiveness. Nanoparticle applications in a tumor setting are inadequate, as demonstrated by the crystallization of DOX within liposomes (Karaosmanoglu et al., 2020). In these strategies, the use

of nanocarriers in patients might bring about unexpected injury and risk. Since liposomal DOX nanoparticles linked with carriers caused the hand-foot syndrome due to DOX crystallization within liposomes (Liu et al., 2024). The improper accumulation ultimately leads to a "protein corona," which deposits on nanodrug formulations and affects their performance. The fundamental toxicity of many inorganic substances, such as heavy metals and the speed at which they gradually accumulate in and remain in the human body gives rise also to safety worries by farmers and consumers (Liu et al.2024). The instability and higher costs of the manufacturing process can inhibit further degrees of spread for nanodrugs, making their introduction into health care usage more difficult. Now, the matter of how to select drug delivery materials is complex and difficult. Researchers with their various mountainsized problems must also consider a long list of far-ranging environmental safety problems (Karaosmanoglu et al., 2020). However, this is no easy job because there are no clear mechanisms associated with tumor cell mutations, metastasis and heterogeneity. Therefore, incomplete knowledge hinders both the overall removal of primary tumors and the prevention of metastases (Vasil et al., 2014).

**Pharmacokinetics and Biodistribution of Nanoparticles-**

This is the new approach of cancer therapies that are ineffective against triple-negative breast cancer. The way in which nanostructures could be employed in a future health care strategy to deliver cutting-edge treatments. Nanoparticles, with their small size, could have different physicochemical properties. They might be able to dodge through ill-defined biological barriers between "properties" and "permutations". It's a major difficulty in today's science to distribute nanoparticles across the body better than not at all with new methods that are more effective and less toxic, it also opens up unimagined possibilities in the future for nano-treatment of cancer in a controlled environment. Unique nanocarriers are developed, such as liposomes or polymeric nanoparticles, to transport medications to tumor sites. This increases the concentration of the drug, increases its bioavailability and decreases the systemic toxicity.

**Resisting Control -**

With the benefit of nanoparticle designs, drug resistance mechanisms in triple-negative breast cancer and other aggressive subtypes of breast carcinoma are beginning to be blocked (Gupta et al., 2024). In compound therapies, nanotechnology makes it possible to combine diverse therapeutic agents or measures in a synergistic way.

## 5.3 Challenges and Limitations of Nanotechnology in Breast Cancer

Nanotechnology has great promise in the diagnosis and treatment of breast cancer by delivering drugs directly to tumors and even cells within them. It can achieve this in many other ways to improve the solubility of drugs or their stability at different pH values and enhance targeted therapies. (Hussain et al., 2018). But a broad acceptance meets many challenges and limitations. While these promising advances exist, obstacles remain for wide clinical application. This includes guaranteeing the continued safety and biological compatibility of nanoparticles, optimizing large-scale production procedures, ensuring reproducibility and addressing regulatory challenges (Sun et al., 2023). Continuous development of research in these areas is essential for moving novel nanotechnologies from the laboratory to clinical practice to improve patient outcomes. Creating nanoparticles with consistent size, shape, surface properties, drug content, and release patterns on a large scale is a complex task. Moreover, the rules for nanomedicines are still being developed and vary widely. This includes safety assessments, studies of long-term effects and quality control, which all present challenges (Abolhassani et al., 2024). Many promising nanoparticle systems are still being tested in preclinical models, like cells and animals, rather than in human trials. In addition, complex multifunctional systems, such as those combining drugs, imaging agents, and stimulus-responsive release mechanisms, can increase manufacturing costs, regulatory risks, and potentially reduce reliability.

Nanotechnology could change how breast cancer is treated in a big way, but it also has a lot of problems and limits. One of the hardest things to do is to find cancer cells without hurting healthy tissues. This is because tumors can be very different from each other, which makes it hard to be sure of specificity. Also, it's still hard to design and keep nanoparticles stable because they need to be small enough to get into tumors but also stable in the blood and break down so they don't become toxic. It's also hard to make sure that the right amount and timing of drugs are given to the tumor site. Nanoparticles can also make people sick and cause immune responses, which makes people worry about how safe they are in the long run. Getting regulatory approval for nanomedicines is also a slow and hard process because there aren't any standard frameworks and it's hard to make enough of them for clinical use. Things are even more complicated by moral questions like how the public sees it and how fair access is, as well as the high costs of development and production. Nanotechnology is still a promising area of research for treating breast cancer, but these issues need to be worked out before it can be used in hospitals all over the world.

## 5.4 Future Perspectives for Nanoparticles in Breast Cancer Treatment

### Personalized Nanomedicine

Nanotherapies for breast cancer are going to be one of the best inventions in oncology. In the next generation, patients can customize their targeted therapies according to their cancer type. For instance, triple-negative breast cancer (TNBC) may benefit from nanoparticles containing immune-modulating drugs, whereas HER2-positive tumors may be treated with HER2-targeted antibody–drug conjugates (ADCs). Genomic sequencing could guide ligand selection for active targeting, ensuring that nanoparticle binding matches the patient's tumor-specific receptors. This personalization aims to increase efficacy while minimizing systemic toxicity (Shi et al., 2017).

### Overcoming Multidrug Resistance (MDR)

One of the primary causes of chemotherapy failure in metastatic breast cancer is still multidrug resistance, which is frequently brought on by P-glycoprotein (P-gp) efflux pumps. By delivering medications intracellularly through endocytosis and avoiding efflux routes, nanoparticles can avoid these pumps. Additionally, nanoparticles can co-deliver gene-silencing agents such as small interfering RNA (siRNA) to suppress the expression of resistance-related genes, restoring drug sensitivity (Wang et al., 2021).

# Chapter 06

## Conclusion

Nanotechnology marks a significant advancement in the fight against breast cancer through targeted and efficient diagnostic and therapeutic strategies.Additionally, nanoparticles can enable earlier and more accurate diagnosis, along with innovative treatment options, including for aggressive and resistant cancers. This precision medicine approach, still under development, shows great promise for optimizing patient management and transforming breast cancer treatment strategies. Scientists and doctors are increasingly turning to nanotechnology, an innovative medical science that can lead to breakthroughs in diagnosis and treatment. Nanotechnology exploits the unique properties of nanoparticles, such as their small size, high surface area, and ability to interact at a molecular level. Although these novel cancer therapies remain in the experimental stage, they have a promising future. However, challenges must be addressed for nanotechnology to significantly contribute to breast cancer care. These include concerns about long-term safety, such as toxicity levels, as well as complexities in manufacturing and regulatory approval. Nevertheless, ongoing research is tackling these issues, with trials evaluating both the effectiveness and safety standards of these new methods. In summary, nanotechnology is a groundbreaking development in the battle against breast cancer. It offers innovative avenues for diagnosis, treatment, and healing. Despite the hurdles, the potential benefits of nanotechnology in breast cancer therapy are

immense and could revolutionize treatments, bringing us closer to personalized, less invasive, and more effective therapies.

**Bibliography:**

Abolhassani, H., Eskandari, A., Saremi Poor, A., Zarrabi, A., Khodadadi, B., Karimifard, S., Sahrayi, H., Bourbour, M., & Tavakkoli Yaraki, M. (2024). Nanobiotechnological approaches for breast cancer Management: Drug delivery systems and 3D In-Vitro models. *Coordination Chemistry Reviews*, *508*, 215754. https://doi.org/10.1016/j.ccr.2024.215754

Blanco, E., Shen, H., & Ferrari, M. (2015). Principles of nanoparticle design for overcoming biological barriers to drug delivery. *Nature Biotechnology*, *33*(9), 941–951. https://doi.org/10.1038/nbt.3330

Bobo, D., Robinson, K. J., Islam, J., Thurecht, K. J., & Corrie, S. R. (2016). Nanoparticle-Based Medicines: A Review of FDA-Approved Materials and Clinical Trials to Date. *Pharmaceutical Research*, *33*(10), 2373–2387. https://doi.org/10.1007/s11095-016-1958-5

Bray, F., Ferlay, J., Soerjomataram, I., Siegel, R. L., Torre, L. A., & Jemal, A. (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. https://doi.org/10.3322/caac.21492

Catalano, E., Geisler, J., & Kristensen, V. N. (n.d.). *Superparamagnetic iron oxide nanoparticles conjugated with doxorubicin for targeting breast cancer*.

Cho, K., Wang, X., Nie, S., Chen, Z. (Georgia), & Shin, D. M. (2008). Therapeutic Nanoparticles for Drug Delivery in Cancer. *Clinical Cancer Research*, *14*(5), 1310–1316. https://doi.org/10.1158/1078-0432.CCR-07-1441

Damasco, J. A., Ravi, S., Perez, J. D., Hagaman, D. E., & Melancon, M. P. (2020). Understanding Nanoparticle Toxicity to Direct a Safe-by-Design Approach in Cancer Nanomedicine. *Nanomaterials*, *10*(11), 2186. https://doi.org/10.3390/nano10112186

Davis, M. E., Chen, Z., & Shin, D. M. (2008). Nanoparticle therapeutics: An emerging treatment modality for cancer. *Nature Reviews Drug Discovery*, *7*(9), 771–782. https://doi.org/10.1038/nrd2614

DeSantis, C. E., Ma, J., Gaudet, M. M., Newman, L. A., Miller, K. D., Goding Sauer, A., Jemal, A., & Siegel, R. L. (2019). Breast cancer statistics, 2019. *CA: A Cancer Journal for Clinicians*, *69*(6), 438–451. https://doi.org/10.3322/caac.21583

Dhiman, R., Bazad, N., Mukherjee, R., Himanshu, Gunjan, Leal, E., Ahmad, S., Kaur, K., Raj, V. S., Chang, C.-M., & Pandey, R. P. (2024). Enhanced drug delivery with nanocarriers: A comprehensive review of recent advances in breast cancer detection and treatment. *Discover Nano*, *19*(1), 143. https://doi.org/10.1186/s11671-024-04086-6

Dissanayake, R., Towner, R., & Ahmed, M. (2023). Metastatic Breast Cancer: Review of Emerging Nanotherapeutics. *Cancers*, *15*(11), 2906. https://doi.org/10.3390/cancers15112906

Dreaden, E. C., Austin, L. A., Mackey, M. A., & El-Sayed, M. A. (2012). Size Matters: Gold Nanoparticles in Targeted Cancer Drug Delivery. *Therapeutic Delivery*, *3*(4), 457–478. https://doi.org/10.4155/tde.12.21

Gupta, A., Nishchaya, K., Saha, M., Naik, G. A. R. R., Yadav, S., Srivastava, S., Roy, A. A., Moorkoth, S., Mutalik, S., & Dhas, N. (2024). Recent advancements in nanoconstructs for the theranostics applications for

triple negative breast cancer. *Journal of Drug Delivery Science and Technology*, *93*, 105401. https://doi.org/10.1016/j.jddst.2024.105401

Hanahan, D., & Weinberg, R. A. (2011). Hallmarks of Cancer: The Next Generation. *Cell*, *144*(5), 646–674. https://doi.org/10.1016/j.cell.2011.02.013

Huang, X., Jain, P. K., El-Sayed, I. H., & El-Sayed, M. A. (2008). Plasmonic photothermal therapy (PPTT) using gold nanoparticles. *Lasers in Medical Science*, *23*(3), 217–228. https://doi.org/10.1007/s10103-007-0470-x

Hussain, Z., Khan, J. A., & Murtaza, S. (2018). Nanotechnology: An Emerging Therapeutic Option for Breast Cancer. *Critical Reviews in Eukaryotic Gene Expression*, *28*(2), 163–175. https://doi.org/10.1615/CritRevEukaryotGeneExpr.2018022771

Jain, R. K., & Stylianopoulos, T. (2010). Delivering nanomedicine to solid tumors. *Nature Reviews Clinical Oncology*, *7*(11), 653–664. https://doi.org/10.1038/nrclinonc.2010.139

Kashtiaray, A., Karimi, M., Ghafori-Gorab, M., & Maleki, A. (2025). A comprehensive review on the recent applications of nanozymes in breast cancer therapy and diagnosis. *Materials Advances*, *6*(10), 3017–3042. https://doi.org/10.1039/D4MA01089B

Kolhe, D. S. U., Funde, M., Rangat, V., & Arkal, R. (2025). *Review Article: "Review On Application Of Nanotechnology In Breast Cancer." 13*(5). Kumar, P., Mangla, B., Javed, S., Ahsan, W., Musyuni, P., Sivadasan, D., Alqahtani, S. S., & Aggarwal, G. (2023a). A review of nanomaterials from synthetic and

natural molecules for prospective breast cancer nanotherapy. *Frontiers in Pharmacology*, *14*, 1149554. https://doi.org/10.3389/fphar.2023.1149554

Kumar, P., Mangla, B., Javed, S., Ahsan, W., Musyuni, P., Sivadasan, D., Alqahtani, S. S., & Aggarwal, G. (2023b). A review of nanomaterials from synthetic and natural molecules for prospective breast cancer nanotherapy. *Frontiers in Pharmacology*, *14*, 1149554. https://doi.org/10.3389/fphar.2023.1149554

Li, Y., Li, X., Li, A., Zhu, J., Lin, Z., & Yang, Y. (2024a). The research trends and future prospects of nanomaterials in breast cancer. *Cancer Nanotechnology*, *15*(1), 24. https://doi.org/10.1186/s12645-024-00261-7

Li, Y., Li, X., Li, A., Zhu, J., Lin, Z., & Yang, Y. (2024b). The research trends and future prospects of nanomaterials in breast cancer. *Cancer Nanotechnology*, *15*(1), 24. https://doi.org/10.1186/s12645-024-00261-7

Miao, L., Kang, Y., & Zhang, X. F. (2024). Nanotechnology for the theranostic opportunity of breast cancer lung metastasis: Recent advancements and future challenges. *Frontiers in Bioengineering and Biotechnology*, *12*, 1410017. https://doi.org/10.3389/fbioe.2024.1410017

Mugundhan, S. L., & Mohan, M. (2024). Nanoscale strides: Exploring innovative therapies for breast cancer treatment. *RSC Advances*, *14*(20), 14017–14040. https://doi.org/10.1039/D4RA02639J

Mura, S., Nicolas, J., & Couvreur, P. (2013). Stimuli-responsive nanocarriers for drug delivery. *Nature Materials*, *12*(11), 991–1003. https://doi.org/10.1038/nmat3776

Nikdouz, A., Namarvari, N., Shayan, R. G., & Hosseini, A. (n.d.). *Comprehensive comparison of theranostic nanoparticles in breast cancer*.Nikita Mane, P. M. (2025). *Innovations In Nanotechnology and Advances in Breast Cancer Treatment*. https://doi.org/10.5281/ZENODO.14587463

Oehler, J. B., Rajapaksha, W., & Albrecht, H. (2024). Emerging Applications of Nanoparticles in the Diagnosis and Treatment of Breast Cancer. *Journal of Personalized Medicine*, *14*(7), 723. https://doi.org/10.3390/jpm14070723

Rahman, M., Afzal, O., Ullah, S. N. M. N., Alshahrani, M. Y., Alkhathami, A. G., Altamimi, A. S. A., Almujri, S. S., Almalki, W. H., Shorog, E. M., Alossaimi, M. A., Mandal, A. K., Abdulrahman, A., & Sahoo, A. (2023). Nanomedicine-Based Drug-Targeting in Breast Cancer: Pharmacokinetics, Clinical Progress, and Challenges. *ACS Omega*, *8*(51), 48625–48649. https://doi.org/10.1021/acsomega.3c07345

Sun, C., Lee, J. S. H., & Zhang, M. (2008). Magnetic nanoparticles in MR imaging and drug delivery. *Advanced Drug Delivery Reviews*, *60*(11), 1252–1265. https://doi.org/10.1016/j.addr.2008.03.018

Sun, S., Wang, Y., Gao, X., Wang, H., Zhang, L., Wang, N., Li, C., & Xiong, S. (2023). Current perspectives and trends in nanoparticle drug delivery systems in breast cancer: Bibliometric analysis and review. *Frontiers in Bioengineering and Biotechnology*, *11*, 1253048. https://doi.org/10.3389/fbioe.2023.1253048

Velapure, P., Kansal, D., & Bobade, C. (2024a). Tumor microenvironment–responsive nanoformulations for breast cancer. *Discover Nano*, *19*(1), 212. https://doi.org/10.1186/s11671-024-04122-5

Velapure, P., Kansal, D., & Bobade, C. (2024b). Tumor microenvironment–responsive nanoformulations for breast cancer. *Discover Nano, 19*(1), 212. https://doi.org/10.1186/s11671-024-04122-5

Wu, X., Luo, L., Yang, S., Ma, X., Li, Y., Dong, C., Tian, Y., Zhang, L., Shen, Z., & Wu, A. (2015). Improved SERS Nanoparticles for Direct Detection of Circulating Tumor Cells in the Blood. *ACS Applied Materials & Interfaces, 7*(18), 9965–9971. https://doi.org/10.1021/acsami.5b02276

Yang, F., He, Q., Dai, X., Zhang, X., & Song, D. (2023). The potential role of nanomedicine in the treatment of breast cancer to overcome the obstacles of current therapies. *Frontiers in Pharmacology, 14*, 1143102. https://doi.org/10.3389/fphar.2023.1143102

# ggh

ORIGINALITY REPORT

| 7% | 4% | 4% | % |
|---|---|---|---|
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | |
|---|---|---|
| 1 | Syeda Warisul Fatima, Shahenvaz Alam, Sunil K. Khare. "Chapter 14 Janus Nano-Assembly Based Sensing Platform for Cancer Theranostics: An Unrivaled Mastering Bioimaging Perspective", Springer Science and Business Media LLC, 2024<br>Publication | 1% |
| 2 | www.jetir.org<br>Internet Source | 1% |
| 3 | www.medicoverhospitals.in<br>Internet Source | <1% |
| 4 | Sougata Jana, Sreejan Manna. "Nanotheranostics - Advances in Biomedical Applications", CRC Press, 2025<br>Publication | <1% |
| 5 | Pearson, Sally A.. "Geographical Disparities in Access to Systemic Anti Cancer Therapies for Advanced Breast Cancer Across Greater Manchester.", The University of Manchester (United Kingdom)<br>Publication | <1% |

| | | |
|---|---|---|
| 6 | imaginis.com<br>Internet Source | <1% |
| 7 | worldwidescience.org<br>Internet Source | <1% |
| 8 | Ejigah, Victor. "Development of Novel Stealth Neratinib and Docetaxel Core-Loaded and Trastuzumab Surface Conjugated Nanoparticle for Treatment of HER2+ Breast Cancer", Howard University, 2025<br>Publication | <1% |
| 9 | www.mdpi.com<br>Internet Source | <1% |
| 10 | diversedaily.com<br>Internet Source | <1% |
| 11 | ualberta.scholaris.ca<br>Internet Source | <1% |
| 12 | www.nj.gov<br>Internet Source | <1% |
| 13 | Shahid Ullah Khan, Muneeb Ullah, Sumbul Saeed, Ebraheem Abdu Musad Saleh et al. "Nanotherapeutic approaches for transdermal drug delivery systems and their biomedical applications", European Polymer Journal, 2024<br>Publication | <1% |

| | | |
|---|---|---|
| 14 | us.huatengsci.com<br>Internet Source | <1% |
| 15 | Ryusei Yoshino, Nozomi Hatanaka, Kengo Takahashi, Akane Ito, Nanami Ujiie, Shunsuke Yasuda, Masahiro Kitada. "Clinicopathological features and prognostic factors of apocrine carcinoma of the breast in a cohort of 63 patients", Discover Oncology, 2025<br>Publication | <1% |
| 16 | pubmed.ncbi.nlm.nih.gov<br>Internet Source | <1% |
| 17 | uwe-repository.worktribe.com<br>Internet Source | <1% |
| 18 | www.bbc.co.uk<br>Internet Source | <1% |
| 19 | Ying Gao, Dongruo Gao, Jie Shen, Qiwen Wang. "A Review of Mesoporous Silica Nanoparticle Delivery Systems in Chemo-Based Combination Cancer Therapies", Frontiers in Chemistry, 2020<br>Publication | <1% |
| 20 | beatcancer.eu<br>Internet Source | <1% |
| 21 | www.ncbi.nlm.nih.gov<br>Internet Source | <1% |

| | | |
|---|---|---|
| 22 | www.realworldhealthcare.org<br>Internet Source | <1% |
| | Franco, Yesenia L.. "Investigating the Effectiveness of Milk-Derived Exosomes to Improve Lapatinib Pharmacokinetic and Pharmacodynamic Profiles", University of Florida, 2025<br>Publication | <1% |
| | Gborogen, Rosilyn. "Experience of African American Women With Mastectomy Without Breast Reconstruction", Wayne State University, 2025<br>Publication | <1% |

| | | | |
|---|---|---|---|
| Exclude quotes | Off | Exclude matches | Off |
| Exclude bibliography | On | | |