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(RESEARCH ARTICLE)

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Altering the potential of nanoencapsulation formulation and digitized transdermal patch combination as a minimal invasive treatment for breast cancer

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Abstract

Background: Breast cancer is a leading cause of cancer-related mortality, accounting for 25% of cancer deaths globally. Despite advances in surgical therapies like lumpectomy, mastectomy, and lymph node dissection, these interventions pose significant risks, including bleeding, infections, and incomplete tumor removal, leading to recurrence. Innovative strategies like nanotechnology integrated with digitalized systems and transdermal patches hold promise for improving treatment outcomes.

Methods: This review explored the potential of nanoencapsulation combined with transdermal delivery and digitalization as a breast cancer therapy. Literature from databases such as PubMed and ScienceDirect, published between 2019 and 2024, was analyzed, focusing on advances in nanotechnology, drug delivery systems, and digitalized therapy. Eleven highly relevant articles informed this review.

Results: The proposed system utilizes nanoparticles for drug encapsulation, enhancing bioavailability and precision. Nanoparticles functionalized for targeted delivery exploit the Enhanced Permeability and Retention (EPR) effect and receptor-specific targeting, such as HER-2. Digital systems optimize drug release in real-time based on patient biomarkers, ensuring controlled and sustained therapy with minimal side effects. Transdermal patches serve as a practical delivery method, offering ease of use, reduced systemic side effects, and enhanced patient compliance.

Conclusion: Integrating nanoencapsulation, digitalization, and transdermal patches provides a revolutionary approach to breast cancer treatment. This minimally invasive method improves therapeutic precision and patient outcomes, reducing the risks associated with conventional therapies. Further research and development are needed to translate this innovation into clinical practice.

Keywords: Nanoencapsulation; Digitized Transdermal Patch; Minimally Invasive Breast Cancer Therapy; Targeted Drug Delivery; Breast Cancer Nanotechnology

1. Introduction

Cancer, or malignant neoplasia, is a medical condition characterized by the uncontrolled growth of abnormal cells, potentially extending and metastasizing from the initial location to surrounding tissues or organs, and possibly reaching other organs through the bloodstream or lymphatic system in the late stages. This disease significantly affects various

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organs and body tissues, such as the skin, lungs, breasts, and digestive tract, with different neoplastic characteristics. Through rapid and uncontrolled cell development, cancer often results in malignant or aggressive tumor masses, which can damage organ function and cause serious complications if not addressed early and appropriately. The global prevalence of cancer continues to rise, with the World Health Organization (WHO) recording approximately 19.3 million new cases and 10 million cancer-related deaths in 2020.[1] Undeniably, cancer has become the leading cause of death worldwide, with varying prevalence depending on the type of cancer and geographical location. The cancer classification system is generally based on the tissue origin of the cancer's appearance, such as breast cancer being tumor cells that become malignant in the breast; cervical cancer in the woman's cervix; and lymph node cancer in the lymphatic system.[2] Breast cancer itself contributes the highest mortality rate with a percentage of 25% of all cancer-related deaths.[3] It doesn't stop there, the low prognosis reaches 30% for 5-year survival in the chronic stage.[4] The diagnostic process for this disease includes histopathological assessment with characteristics of abnormal and atypical cell hyperplasia. Additionally, other characteristic features of malignancy include hyperchromatic nuclei and cellular dysplasia with hyperparakeratosis and dyskeratosis in massive amounts.

The approach most frequently taken as an intervention for breast cancer involves invasive surgical therapies such as lumpectomy, mastectomy, and lymph node dissection. Each type of surgical management is intended for different stages of breast cancer indications. For example, lumpectomy is aimed at the early stage; mastectomy at the moderate stage; and lymph node dissection becomes an advanced therapy performed when extensive indications and metastasis of cancer cells from the breast to the lymph nodes have been found. Of course, there is a reason why these three types of therapies are the choice of clinicians in treating breast cancer, considering the quite prominent success rates of their removal. However, every surgical procedure always carries a significant risk of bleeding, which can become a port of entry and open a pathway for secondary infections for the patient. This bleeding process cannot be overlooked considering the amount of blood lost during the procedure, which drastically reduces the human immune system. As a result, the risk of secondary infections caused as a domino effect will greatly affect the recovery rate of the bleeding wound and the patient's recovery from cancer.[5] In addition, other aspects such as the characteristic of cancer that easily grows and develops progressively if the removal is not done cleanly and thoroughly, coupled with bleeding as an optimal medium for cancer cells and damage that triggers a hyperinflammatory response, support its progressiveness, resulting in this invasive management actually turning into a failure within weeks or even days after breast cancer removal.

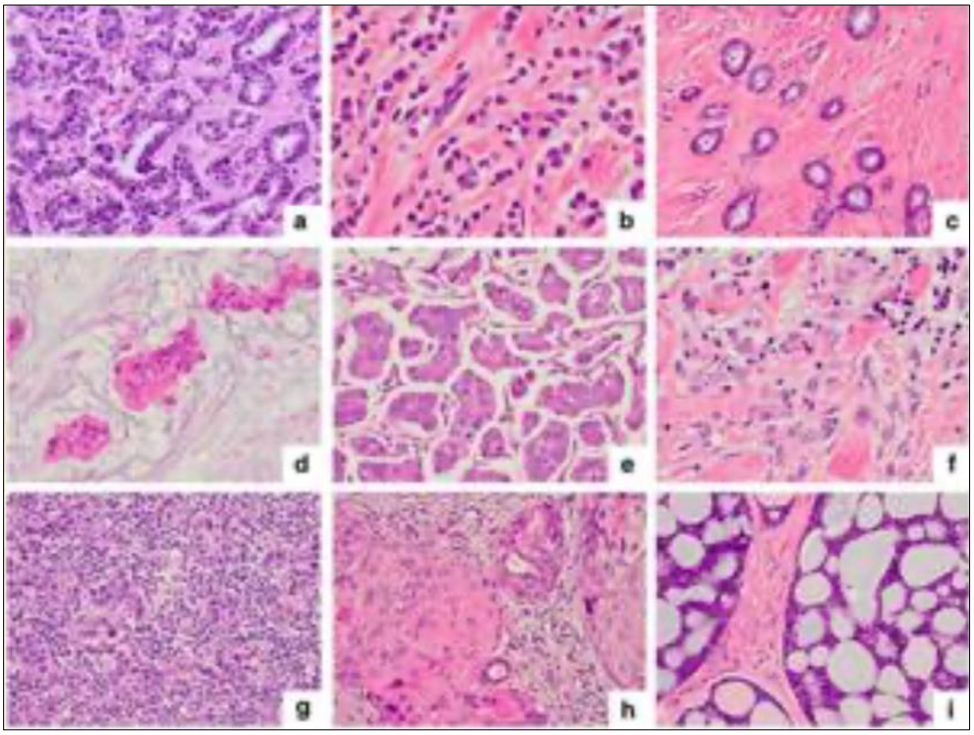

Figure 1 Microscopical Feature of Breast Cancer

Considering the domino effect and its limited affordability due to price and the distribution of qualified clinicians in Indonesia, a revolution in breast cancer management needs to be carried out through more minimally invasive therapies that are affordable and easy to use. Recently, nanotechnology has been rapidly developing, not only in the industrial world but also in the medical field, which is beginning to utilize the myriad benefits of nanotechnology to address the

shortcomings and weaknesses of conventional therapies. In this discussion, a nanotechnology system for encapsulating therapeutic active ingredients with administration through a transdermal patch, regulated by a digitalization system, is presented to enhance the precision of drug delivery systems in breast cancer cases.

2. Material and methods

A literature review exploring the potential of nanoencapsulation formulation and its incorporation with transdermal patch and digitalization as a therapeutic method for breast cancer, was conducted by searching and compiling scientific articles and data. These form the foundation and provide supporting evidence for arguments favouring the potential of this incorporation in breast cancer treatment. Articles and data were sourced from reputable scientific databases, such as PubMed, ScienceDirect, ResearchGate, and supplementary databases like Google Scholar, to gather research findings relevant to the situation in Indonesia, which aligns with the objectives of this literature review.

Several key phrases were used to aid the search process, including terms related to nanoencapsulation, nanotechnology, transdermal patch, digitalization, digitized transdermal patch, breast cancer, breast carcinoma, and breast malignancy. Another aspect considered during the collection process was ensuring that the articles and data were up-to-date. Only articles published within the last five years were selected, with the oldest articles being from 2019.

A total of 180 articles were retrieved through the search process and were gradually filtered based on their relevance to the objectives of the literature review. Ultimately, 11 related articles were used in the preparation of this review.

3. Results and discussion

This system incorporates advanced drug nanoencapsulation based on nanoparticles to enhance the effectiveness and efficacy of breast cancer therapy. Nanoparticles, which are sized between 1 to 100 nanometers, are designed with a spherical shape and morphology that can be confirmed through electron microscopy characterization tests and X-ray diffraction to ensure size consistency and distribution accuracy.[5] The physicochemical properties of nanoparticles, such as chemical stability and solubility, are designed to enhance the bioavailability of therapeutic active compounds with adjustable surface charges to maximize direct interactions with targeted cancer cells and reduce side effects. The main advantage of this system certainly lies in its ability to protect active compounds from biodegradation, thereby optimizing lower doses and reducing the frequency of administration due to the controlled and targeted release of therapeutic active compounds comprehensively.[6] Regarding the targeting of breast cancer cells, implementation through this system can utilize surface modification of nanoparticles with ligands or antibodies specific to breast cancer receptors, such as HER-2.[7] Additionally, nanoparticles designed to release therapeutic active compounds in the low pH environment around cancer cells utilize the EPR (Enhanced Permeability and Retention) effect to enhance the accumulation of therapeutic active compounds in cancer tissue, considering the poor lymphatic drainage system and high capillary permeability in that tissue.[8] The agents used in this system—whether chemotherapy, targeted therapy, or hormonal therapy—are formulated with nanoparticles to enhance the treatment efficiency against breast cancer.

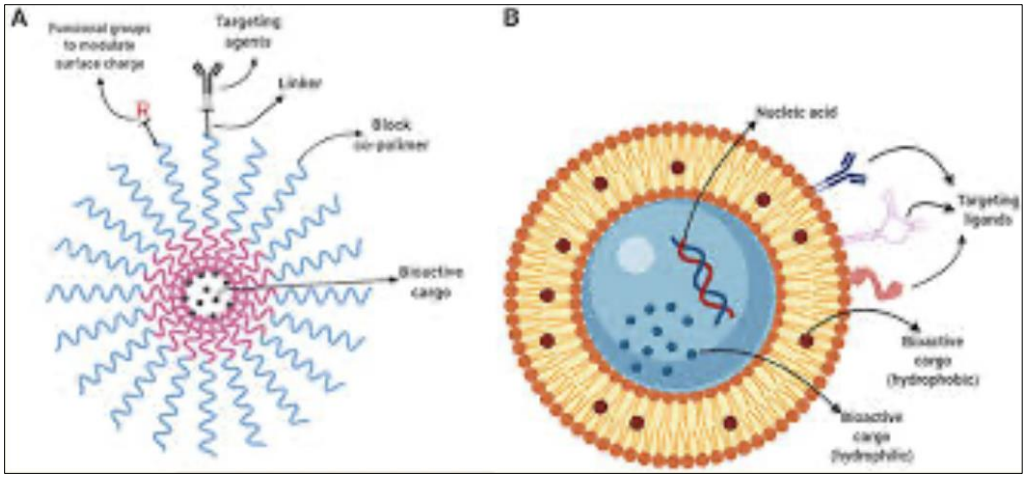

Figure 2 Blueprint of Nanoencapsulation Formulation Design

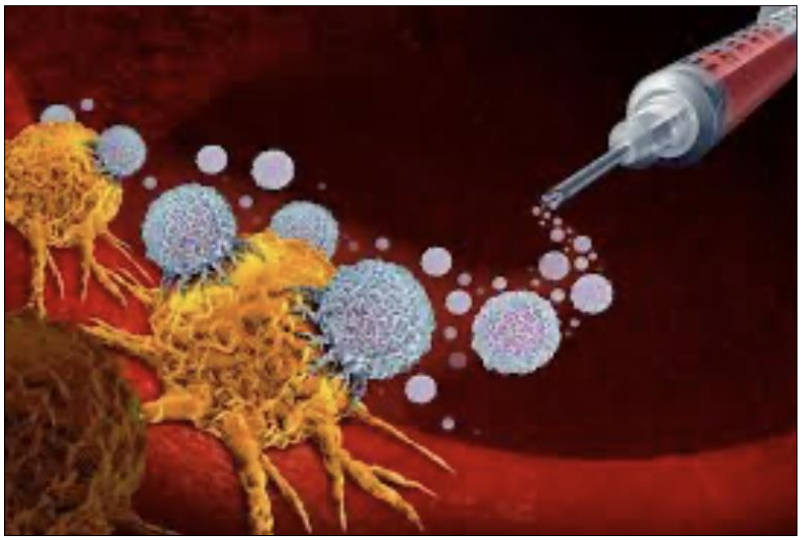

Figure 3 Implementation Scheme of Nanoencapsulation Formulation in Targetting Breast Cancer Specifically

Furthermore, this innovation is also supported by a digitalization system in controlling the release of nanoparticle formulations, offering a highly sophisticated and targeted approach in breast cancer treatment. This technology encourages precise dose regulation, ensuring that active compounds are administered in the correct amounts and frequencies according to treatment protocols, which is extremely important. Through a digital interface, doctors can program doses accurately, reducing the risk of overdose or underdose and ensuring more effective therapy.[9] In its implementation, the digitalization system equipped with sensors and real-time monitoring technology encourages the adjustment of nanoparticle release based on direct feedback from the patient's body condition. The collected data, such as changes in biomarkers or physiological parameters, are used to dynamically adjust the release rate of therapeutic active compounds. Thus, the active compounds can be precisely released in the target area, such as cancer tissue, based on the specific conditions and treatment needs of the patient. As a result, this system is also integrated with telemonitoring technology that helps doctors monitor patient treatment in real-time and adjust therapy based on the latest conditions. Through digital connectivity, data on the use of nanoparticles and treatment responses can be accessed by healthcare professionals, optimizing adjustments that are more personalized and responsive to changes in the patient's condition. Integration with electronic medical records also enhances medication adjustments based on genetic profiles and health history, further increasing therapy effectiveness and reducing side effects.

Figure 4 Approximation of Digitalization System for the Product

The next step is to integrate the digitalized nanoencapsulated therapeutic active compound system into a mode of administration that is practical, efficient, easy, inexpensive, and precise, thereby supporting this prototype. This

innovation highlights the use of transdermal patches as an innovative and solution-oriented step in breast cancer treatment, where the nanoencapsulation formulation, designed to protect therapeutic active compounds and optimize controlled release, will be loaded into the patch. The tapered size of the patch also allows for integration with digital technology, which can enhance precise dosing of active compounds, as well as adjust the timing and amount of release according to the patient's needs.[10] Furthermore, the transdermal patch was chosen as the ideal option for this technology for several reasons, as this patch offers ease and convenience, since patients only need to attach the patch to the breast area to receive the active compounds gradually, considering that this patch supports controlled and sustained release of active compounds, thanks to a digital system that monitors and adjusts the dosage in real-time. This can also help maintain stable drug levels in the blood, enhance therapeutic efficacy, and reduce the frequency of administration. In addition, transdermal patches can also reduce systemic side effects that often occur with other drug administration methods, such as injections or pills. By delivering active compounds directly through the breast skin into the systemic circulation, these patches minimize the interaction of active compounds with other body organs, reducing the likelihood of side effects and enhancing patient safety.[11] Therefore, the transdermal patch integrated with this innovation can be the perfect combination as an efficient, comfortable, and effective interventional solution to utilize digitized nanoencapsulation technology in the administration of therapeutic active compounds for breast cancer treatment.

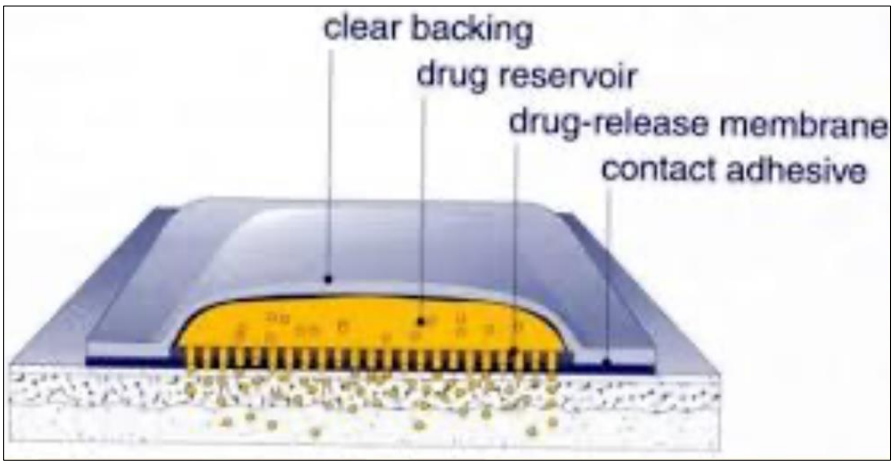

Figure 5 Conceptual Design of Controlled and Precised Drug Release Through Transdermal Patch

The integration of a digitized nanoencapsulation system with a transdermal patch offers several significant advantages in the administration of therapeutic active compounds for breast cancer. First, this system allows for the controlled and sustained release of active compounds through a transdermal patch, maintaining stable levels of active compounds in the blood and reducing the frequency of administration. The integrated digital technology with the patch allows for high-precision dose adjustments, so the active compound dosage can be programmed and adjusted in real-time according to the patient's needs, optimizing therapy effectiveness while minimizing the risk of overdose or underdose. The ease and convenience of using transdermal patches are also major advantages, as patients only need to apply the patch to the breast skin, reducing the discomfort often associated with injections or pills. Additionally, the delivery of active compounds directly through the breast skin to the systemic circulation reduces drug interactions with other body organs, minimizing unwanted systemic side effects and enhancing patient safety. The digital system allows for real-time monitoring and adjustments, providing data that can be used to tailor drug release according to changes in the patient's condition, thereby enhancing therapy effectiveness. Transdermal patches also improve patient adherence to medication regimens by reducing the frequency of administration and making the delivery of therapeutic active compounds more accessible. Flexibility in the design and application of nanoencapsulation systems allows for the creation of patches for various types of drugs and therapies, as well as adaptation to the specific needs of patients. Overall, the combination of this technology offers an efficient and sophisticated solution for the administration of active compounds, enhancing the effectiveness of treatment while minimizing risks and discomfort for patients.

4. Conclusion

This innovation could be a revolutionary solution in breast cancer treatment, combining nanotechnology, digitalization systems, and transdermal patches to enhance therapy effectiveness. This technology is designed for application on the breast area, allowing for the release of therapeutic active compounds that are more precise, controlled, and targeted. This approach aims to improve breast cancer prognosis in a minimally invasive manner and reduce the risk of

malignancy progression. Breas7ech highlights seven main features resulting from the integration of these three technologies. These features include: controlled and sustained release of active drug compounds, precise dose adjustment, ease and convenience of use, minimization of systemic side effects, optimization of patient compliance, and flexibility in design and application. These features ensure more effective and comfortable therapy for patients, while minimizing negative impacts and improving treatment outcomes.

Compliance with ethical standards

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Disclosure of conflict of interest

Authors have declared no conflict of interests.

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