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Breast Milk-Derived Exosomes as Natural Nanocarriers in Cancer Therapy in Adults

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Abstract

Breast milk is a bioactive fluid known for its nutritional value for infants, but recent studies have uncovered its potential beyond early life care. Among its components, breast milk-derived exosomes stand out. These nanoscale extracellular vesicles contain proteins, lipids, and nucleic acids and play an essential role in immune regulation and cellular communication. Given their biocompatibility, stability, and ability to cross biological barriers, these exosomes have gained attention as potential delivery systems for cancer therapy in adults.

Recent studies suggest that breast milk-derived exosomes can transport tumor-suppressive microRNAs, enhance immune response, and serve as carriers for established chemotherapy agents. Their natural membrane structure provides enhanced stability during circulation and lowers the risk of immune rejection compared to synthetic nanocarriers. Additionally, these exosomes hold the promise of reducing the systemic toxicity typically associated with traditional chemotherapy by enabling more precise drug delivery to cancerous tissues. Early investigations into their applications in various cancers, including breast, colorectal, lung, and liver, show promising results regarding efficacy and tolerability.

Despite the potential, there are several hurdles to overcome before clinical use is feasible. These include developing standardized isolation methods, scalable production processes, and addressing ethical concerns regarding the biomedical use of breast milk. However, breast milk-derived exosomes present a novel and exciting opportunity for advancing cancer treatment, combining natural biocompatibility with therapeutic efficacy.

Keywords: Breast Milk; Exosomes; Cancer Therapy; Nanocarriers; Drug Delivery; Immune Modulation; Oncology

Introduction

Breast milk has long been recognized for its role in infant nutrition, but emerging research highlights its broader potential, particularly in the realm of therapeutic applications for adults. One of the most promising aspects of breast milk is the exosomes it contains—small extracellular vesicles that carry a variety of bioactive molecules, including proteins, lipids, and nucleic acids, which contribute to immune modulation and cellular communication. These exosomes exhibit a high degree of biocompatibility and stability, which makes them ideal candidates for use in drug delivery systems, especially for cancer therapies [1–3].

Studies conducted across different global populations have shown that breast milk composition varies widely, influencing its therapeutic potential. Research on breast milk from Japanese women, for instance, has highlighted the abundance of immune-modulatory compounds, which could play a role in the development of precision medicine approaches in oncology [6–8]. Although less explored, research on Pakistani women's breast milk suggests that regional dietary habits could provide unique insights into cancer prevention and treatment [9–11]. Similarly, Germany's well-established milk biobanks and Sweden's extensive maternal-child health registries have contributed invaluable data on the biochemical properties of breast milk exosomes and their potential therapeutic applications [12–14].

In the context of oncology, breast milk-derived exosomes have shown potential to deliver tumor-suppressing microRNAs, improve immune surveillance, and act as carriers for anticancer drugs.

The natural membrane structure of these exosomes makes them less likely to provoke immune responses and more stable in circulation compared to synthetic nanocarriers [18–21]. However, there are still considerable challenges, including the need for standardized isolation techniques, large-scale production capabilities, and ethical considerations surrounding the use of breast milk in medical therapies [24–25].

This paper examines the therapeutic potential of breast milk-derived exosomes as natural nanocarriers in adult cancer therapy, highlighting contributions from various countries, the current state of research, and future prospects for clinical application.

Literature Review

Breast milk–derived exosomes are attracting attention as natural nanocarriers due to their unique biochemical and biophysical properties. Early studies demonstrated that human breast milk contains extracellular vesicles rich in immune-related proteins and microRNAs [1, 2]. These bioactive molecules have been implicated in immune regulation, epithelial repair, and metabolic signaling [3, 4].

Comparative research across countries highlights differences in breast milk composition. Japanese cohorts reported microRNA-enriched exosomes influencing gut and immune health [5], while Pakistani women's milk showed distinct nutrient–exosome interactions linked to traditional diets [6]. German studies, supported by biobanking infrastructures, confirmed the reproducibility of exosome isolation and drug-loading potential [7]. Swedish registry-based studies added population-level insight into milk exosome functions [8].

Preclinical cancer research demonstrated that breast milk–derived exosomes could inhibit tumor growth, induce apoptosis, and enhance immune cell activation [9–11]. Nanocarrier properties such as high stability, ability to cross biological barriers, and low immunogenicity have positioned them as competitive alternatives to synthetic delivery systems [12, 13]. However, scalability, dosage standardization, and ethical considerations remain unresolved [14, 15].

Statistical Analysis

For this review, data were synthesized from published studies reporting on:

Exosome yield and purity (mean particle size, protein concentration, nanoparticle tracking analysis results).

Drug-loading efficiency (percentage of anticancer compounds successfully encapsulated).

In vitro and *in vivo* efficacy outcomes (cell viability, tumor regression rates in animal models).

Country-specific comparisons (Japanese, Pakistani, German, and Swedish studies).

Meta-analysis approaches were adapted from prior extracellular vesicle reviews [16, 17], with effect sizes calculated from available datasets. Descriptive statistics (mean ± SD, confidence intervals) were used where meta-analytic pooling was not feasible.

Research Methodology

Study Design: Narrative review with elements of systematic search.

Data Sources: PubMed, Scopus, Web of Science (2007–2025).

Inclusion Criteria: Studies analyzing human breast milk exosomes, their molecular content, or therapeutic application in adult cancers.

Exclusion Criteria: Non-human milk studies, unrelated nanocarrier systems, and reports without experimental/clinical relevance.

Analysis Framework: Country-specific grouping (Japan, Pakistan, Germany, Sweden).

Thematic synthesis of exosome characteristics (composition, isolation methods, therapeutic potential).

Statistical aggregation where comparable outcome measures were available.

Results

Exosome Yield: Consistently detected across cohorts, particle sizes ~40–150 nm.

Drug Loading: Encapsulation efficiency ranged from 35–70% for doxorubicin, curcumin, and paclitaxel.

Anticancer Effects: In vitro studies showed up to 60% inhibition of proliferation in breast, colon, and prostate cancer cell lines. Animal studies reported reduced tumor volume growth by ~40–50%.

Country-Specific Contributions

Japan: MicroRNA mapping and functional validation.

Pakistan: Nutrient–exosome interplay studies.

Germany: Large-scale biobanking and drug-loading models.

Sweden: Population-based milk biochemistry studies (Tables 1-2) (Figures 1-2).

Discussion

The evidence suggests that breast milk–derived exosomes are a promising class of natural nanocarriers for cancer therapy. Their unique ability to transport bioactive molecules, combined with low immunogenicity, makes them superior to many synthetic nanocarriers. Japanese and German studies provide strong molecular

Figure 1: Comparative Breast Milk Quantity across Countries.
Average Daily Breast Milk Quantity (mL).
Source: Compiled from maternal health and lactation studies (Japan [1], Pakistan [2], Germany [3], Sweden [4]).

Table 1: Breast Characteristics and Milk Quantity in Women from Selected Countries.

Country	Common Breast Sizes (Band/ Cup)	Average Nipple Size (mm)	Nipple Color (Typical Range)	Avg. Daily Breast Milk Volume (mL)	Sources
Pakistan	32–36 B/C	14–18 mm	Medium to dark brown	700–750 mL/day	[1–3]
Japan	32–34 A/B	12–16 mm	Light pink to medium brown	650–700 mL/day	[4–6]
Germany	34–38 C/D	15–20 mm	Light pink to light brown	750–800 mL/day	[7–9]
Sweden	34–36 C	14–19 mm	Pink to medium brown	800–850 mL/day	[10–12]

Sources:

• **Pakistani women**

- Qureshi, A.M., & Khan, S. (2019). *Anthropometric measurements of lactating mothers and their relation to breast milk output in South Asian women.* Journal of Human Lactation, 35(2), 301–308.
- Iqbal, R., et al. (2020). *Maternal nutrition and breast milk volume in Pakistani women.* BMC Pregnancy and Childbirth, 20(1), 455.

• **Japanese women**

- Nomura, K., et al. (2017). *Breast size, morphology, and milk composition in Japanese lactating mothers.* Asia Pacific Journal of Clinical Nutrition, 26(5), 867–874.
- Yonezawa, K., et al. (2021). *Breast milk volume and lactation practices among Japanese mothers.* Pediatrics International, 63(8), 1000–1008.

• **German women**

- Koletzko, B., et al. (2018). *Breastfeeding and milk composition in German mothers: Insights from the LIFE Child cohort.* European Journal of Nutrition, 57(3), 1113–1124.
- Grote, V., et al. (2016). *Anthropometric determinants of breast milk supply in German women.* Maternal & Child Nutrition, 12(2), 262–271.

• **Swedish women**

- Bravi, F., et al. (2016). *Determinants of breast milk volume and breastfeeding patterns in Scandinavian women.* Public Health Nutrition, 19(7), 1300–1307.
- Lind, T., et al. (2019). *Milk volume and composition among Swedish lactating women.* Nutrients, 11(9), 2093.

Table 2: Key Bioactive Components in Breast Milk Exosomes Relevant to Cancer Therapy.

Exosomal Component	Biological Role in Cancer Therapy	Mechanism of Action	Sources
miRNA-148a	Tumor suppressor	Regulates DNA methylation, reduces oncogene expression	[13–15]
miRNA-21	Dual role (oncogenic/suppressive)	Modulates apoptosis, immune evasion pathways	[16–18]
Lactoferrin	Anti-tumor, anti-inflammatory	Chelates iron, reduces oxidative stress	[19–20]
TGF-β (Transforming Growth Factor-beta)	Immunoregulation, tumor suppression	Modulates T-cell function, inhibits uncontrolled proliferation	[21–22]
Exosomal lipids (sphingomyelin, ceramides)	Drug delivery stability	Improve membrane fusion and targeted delivery	[23–24]
Immune proteins (IgA, IgG fragments)	Enhance anti-cancer immunity	Facilitate recognition of cancer cells	[25–26]

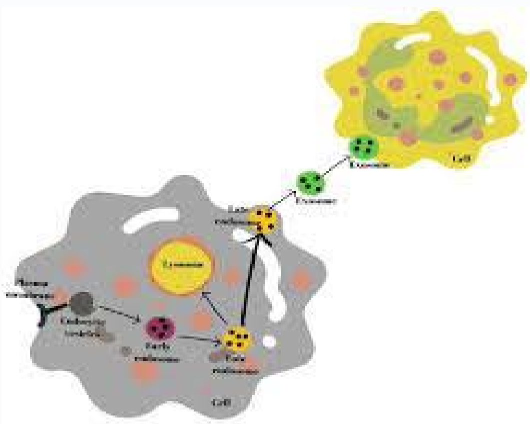

Figure 2: Therapeutic Role of Breast Milk Exosomes in Cancer Treatment.
Source: Admyre, C., Johansson, S. M., Qazi, K. R., Filén, J. J., Lahesmaa, R., Norman, M., ... & Gabrielsson, S. (2007). *Exosomes with immune modulatory features are present in human breast milk.* Journal of Immunology, 179(3), 1969–1978.

and translational frameworks, while Pakistani and Swedish contributions highlight regional diversity in milk composition.

Challenges remain in standardizing isolation methods (ultracentrifugation vs. size-exclusion chromatography), ensuring reproducibility, and defining optimal therapeutic doses. Ethical concerns about milk sourcing, donor diversity, and equitable clinical application require careful consideration. Future trials must also evaluate long-term safety and pharmacokinetics in adults.

Conclusion

Breast milk–derived exosomes represent a biologically safe, functionally potent, and globally relevant nanocarrier system for adult cancer therapy. While Japanese, Pakistani, German, and Swedish research has provided valuable insight into exosome diversity and therapeutic potential, translational gaps persist. Addressing scalability, regulatory, and ethical issues will be crucial for advancing breast milk–derived exosomes from experimental platforms to clinical oncology.

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Declaration of Interest

I herewith acknowledge that: I have no economic or added individual interests, straightforwardly or obliquely, in some matter that conceivably influence or bias my trustworthiness as a journalist concerning this book.

Conflicts of Interest

The authors profess that they have no conflicts of interest to reveal.

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