[Commentary] Impact of Total Mastectomy on the Lymphatic Pathway and the Limitation of PET Imaging in Breast Cancer Surveillance

Maher M. Akl[1], Amr Ahmed[2]

1 Mansoura University
2 Ministry of Health Saudi Arabia

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Abstract

Breast cancer, a multifaceted disease characterized by the uncontrolled proliferation of cells within breast tissue, presents a significant health challenge worldwide. Its etiology is complex, involving intricate interactions between genetic, hormonal, environmental, and lifestyle factors. Recent advancements in research and clinical practice have led to the development of various therapeutic modalities aimed at combating this formidable adversary. Total mastectomy, a surgical intervention involving the complete removal of breast tissue, accompanied by axillary lymph node dissection, remains a cornerstone in breast cancer management. However, this procedure can disrupt the intricate lymphatic network, leading to lymphedema, a debilitating condition characterized by the accumulation of lymphatic fluid. Lymphatic metastases post-total mastectomy and axillary dissection pose a significant clinical challenge, often involving the spread of cancerous cells via the lymphatic route. The process of metastatic development following complete breast resection is multifactorial and influenced by various mechanisms. Additionally, axillary lymph node dissection itself can inadvertently disseminate cancer cells into the lymphatic system, posing a risk for the development of lymphatic metastases. Positron emission tomography (PET) scan plays a crucial role in breast cancer surveillance, offering a non-invasive means of monitoring disease recurrence and metastatic spread. However, its efficacy in detecting lymphatic metastases is limited due to lower metabolic activity compared to other types of metastases. This highlights the need for continued research and innovation to improve the detection and management of lymphatic metastases in breast cancer patients undergoing mastectomy and lymph node dissection.

Maher Monir. Akl[1]

Department of Chemistry, Faculty of Science, Mansoura University, 35516, Mansoura, Egypt.

ORCID iD: 0000-0001-5480-1688

Amr Ahmed[2]

The public health department, Riyadh First Health Cluster, Ministry of Health, Saudi Arabia.

ORCID iD: 0000-0003-3477-236X

*Correspondence
Maher Monir. Akl
Department of Chemistry, Faculty of Science,
Mansoura University, 35516, Mansoura, Egypt.
Phone: +201020432031
E-mail: maherakl555@gmail.com
ORCID iD: 0000-0001-5480-1688

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Commentary

Breast cancer is a multifaceted disease characterized by the malignant proliferation of cells within breast tissue. Its etiology is intricate, involving a multitude of genetic, hormonal, environmental, and lifestyle factors contributing to its pathogenesis and progression. Over the years, advancements in research and clinical practice have deepened our understanding of breast cancer biology, leading to the development of various therapeutic modalities aimed at combating this formidable adversary [1]. One such therapeutic intervention is total mastectomy, a surgical procedure involving the complete removal of breast tissue, often accompanied by axillary lymph node dissection to assess disease spread and facilitate regional control. While total mastectomy remains pivotal in breast cancer management, its implementation can profoundly affect the lymphatic pathway, particularly through disruption or damage to axillary lymph nodes and lymphatic vessels [2].

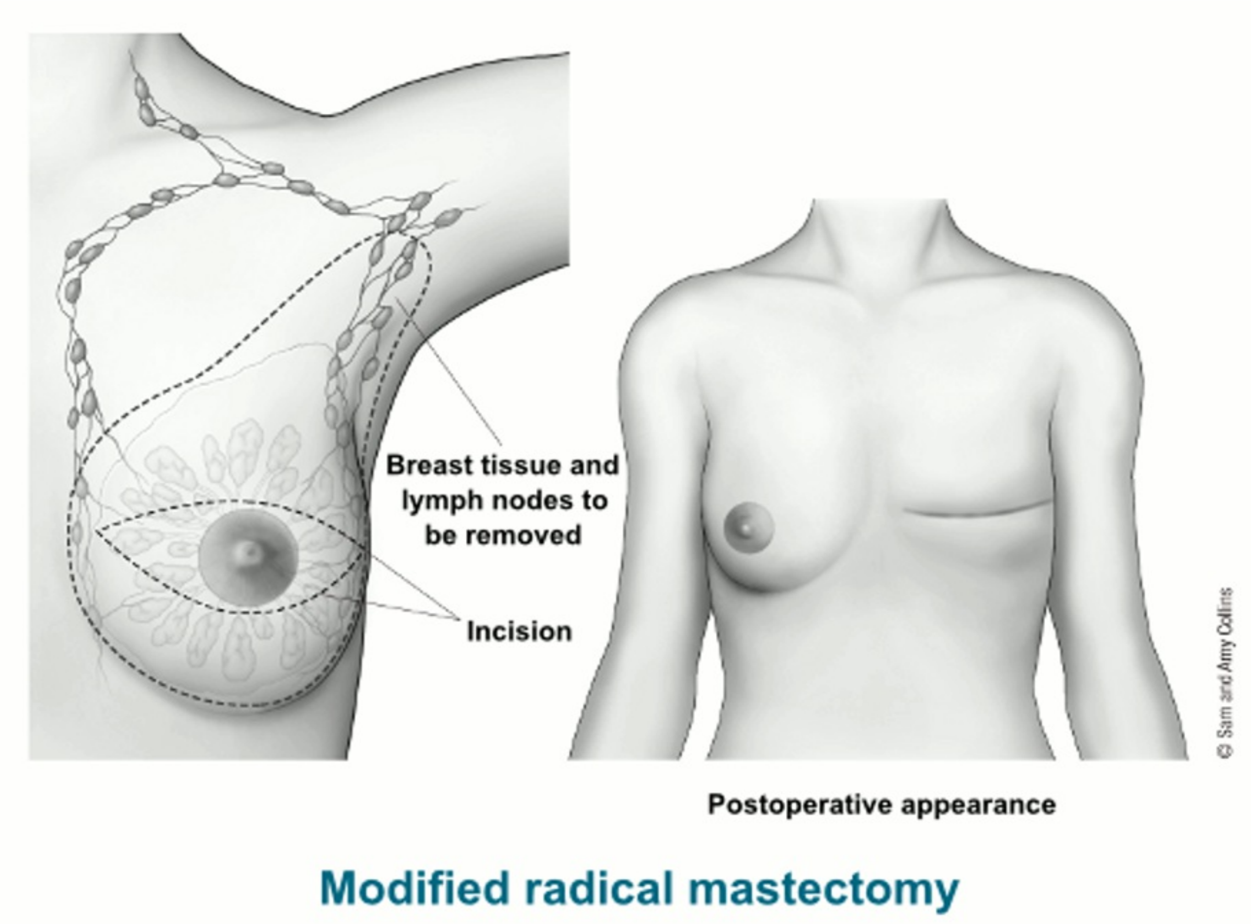

Figure 1. It illustrates a total mastectomy procedure, a crucial surgical intervention in breast cancer treatment. It showcases the meticulous technique used to remove all breast tissue, including the mammary gland, to eradicate cancer cells and prevent disease recurrence. Sourced from the American Cancer Society .

The negative impact of total mastectomy on the lymphatic system arises from the disruption of normal lymphatic drainage pathways, leading to lymphedema, a debilitating condition characterized by the accumulation of lymphatic fluid in interstitial spaces, typically resulting in swelling and discomfort in the affected limb.

Lymphedema poses physical and psychological burdens on patients and predisposes them to secondary complications such as cellulitis, lymphangitis, and impaired wound healing, compromising their overall quality of life and long-term prognosis [3].

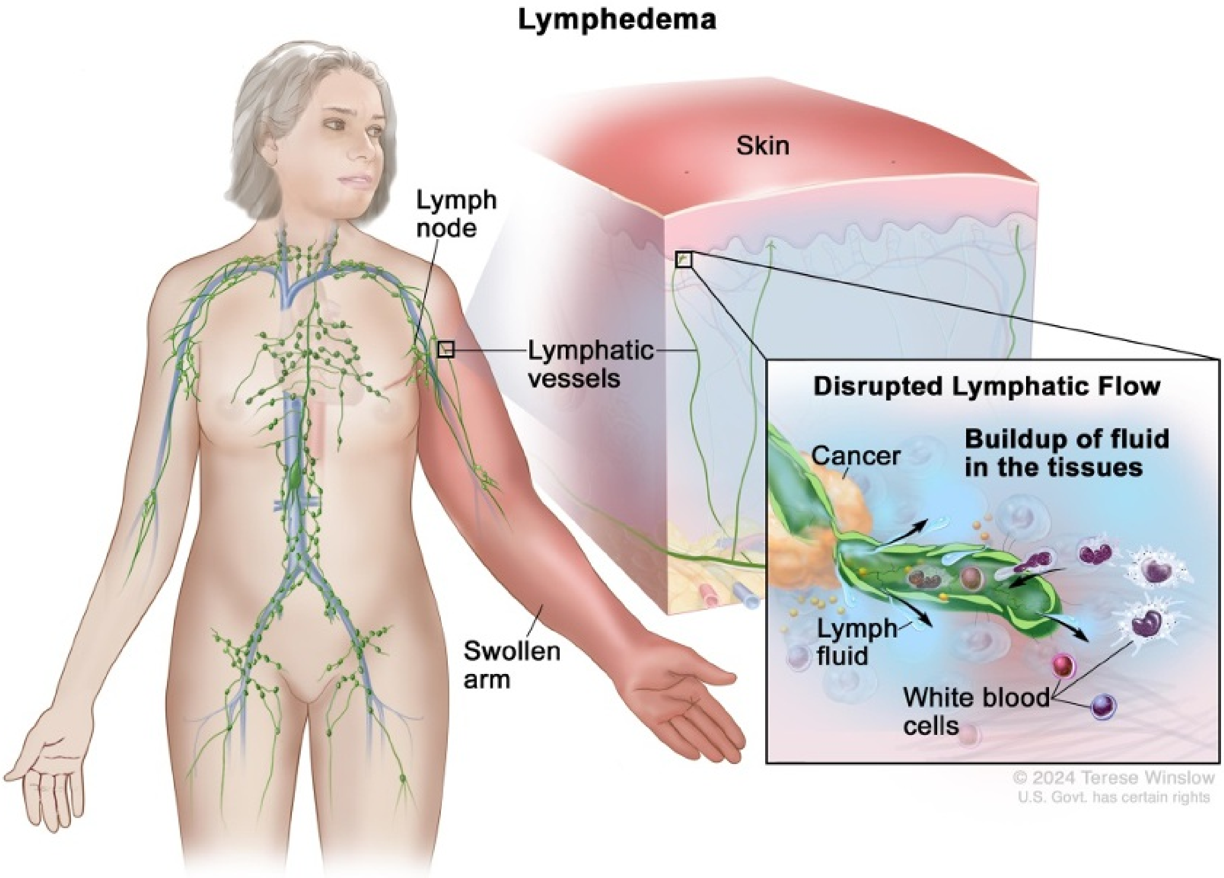

Figure 2. The intricate network of the lymphatic system, essential for the body's immune defense, comprising lymph nodes, lymphatic vessels, and organs responsible for lymph fluid transport. Disruption of this balance due to cancer or its treatment, such as total mastectomy and axillary dissection, can lead to lymph accumulation, resulting in lymphedema. This depiction underscores the interconnectedness of breast and axillary lymph nodes and their significance in facilitating the spread of cancer cells through the lymphatic pathway. Figure source: National Cancer Institute .

Breast cancer metastases post-total mastectomy and axillary dissection pose a significant clinical challenge, often involving the spread of cancerous cells via the lymphatic route. The process of metastatic development following complete breast resection is multifactorial, influenced by various mechanisms contributing to the dissemination and progression of cancer cells within the lymphatic system [4]. One key mechanism driving lymphatic metastases post-mastectomy is the disruption of normal lymphatic drainage pathways. Total mastectomy involves removing the primary tumor along with adjacent breast tissue and often necessitates axillary lymph node dissection to assess regional lymph node involvement. This surgical intervention disrupts the natural flow of lymphatic fluid within the axillary basin, creating a microenvironment conducive to the seeding and proliferation of cancer cells [5]. Moreover, the removal of axillary lymph nodes during surgery not only disrupts normal lymphatic flow but also eliminates key anatomical barriers that would otherwise impede cancer cell dissemination. Lymphatic vessels serve as conduits for cancer cells to migrate from the primary tumor site to regional lymph nodes and beyond, facilitating the establishment of secondary metastatic foci. The loss of axillary lymph nodes as a result of surgical resection diminishes the body's defense against cancer spread, thereby enhancing the likelihood of lymphatic metastases post-mastectomy [6][7].

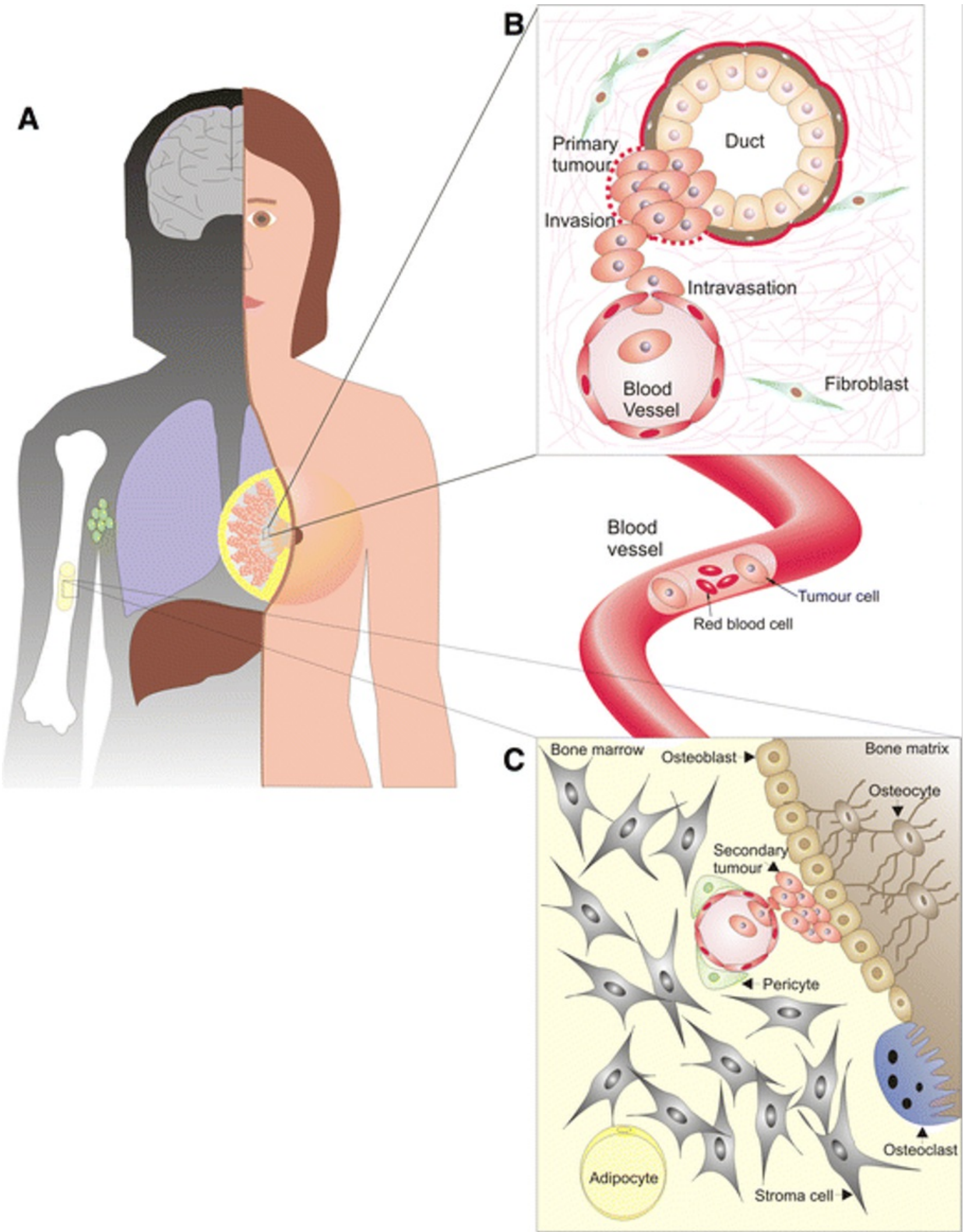

Figure 3. Breast cancer metastasis is depicted in three stages. Firstly, breast cancer commonly spreads to the bone, lymph nodes, liver, lung, and brain. Secondly, tumor cells are shown detaching from the primary breast tumor and infiltrating the surrounding tissue, eventually reaching lymph or blood vessels. Thirdly, breast tumor cells that enter the bloodstream are transported to distant organs like the bone. Upon reaching the bone marrow, these cells adhere to the tissue, initiating changes in the microenvironment to promote bone degradation. This illustration emphasizes the connection between breast and axillary lymph nodes and their role in facilitating the dissemination of cancerous cells through the lymphatic pathway [8].

Additionally, the process of axillary lymph node dissection itself can inadvertently disseminate cancer cells into the lymphatic system. Surgical manipulation of the axilla may disrupt tumor capsules or lymphatic vessels, leading to the release of cancer cells into the lymphatic circulation.

This phenomenon, known as iatrogenic tumor dissemination, poses a significant risk for the development of lymphatic metastases and underscores the importance of surgical precision and meticulous technique in minimizing this potential complication [9]. Positron emission tomography (PET) scan plays a pivotal role in the surveillance of breast cancer patients, particularly following total mastectomy and axillary dissection. This imaging modality utilizes radioactive tracers, such as fluorodeoxyglucose (FDG), to detect areas of increased metabolic activity indicative of malignancy. PET scan offers a non-invasive means of monitoring disease recurrence and metastatic spread by identifying hypermetabolic lesions in the breast bed, axilla, and distant sites [10].

The principle behind PET scan involves the administration of a radiotracer, taken up by cells with high metabolic rates, such as cancer cells. Emitted positrons from the radioactive decay of the tracer collide with electrons, resulting in the production of gamma rays detected by a PET scanner. By mapping the distribution of radioactive emissions within the body, PET scan generates images reflecting tissue metabolic activity, allowing for the identification of cancerous lesions and assessment of disease burden [11]. However, despite its utility, PET scan has limitations in detecting certain types of metastases, particularly those spread via the lymphatic route post-total mastectomy and axillary dissection. Breast cancer cells preferentially disseminate through lymphatic vessels, rendering lymphatic metastases less conspicuous on PET imaging compared to hematogenous metastases with higher metabolic activity [12][13]. Carcinoma erysipeloides, a rare subtype of cutaneous metastasis, exemplifies the challenge of lymphatic spread in breast cancer. This manifestation occurs when cancer cells embolize into lymphatic vessels and infiltrate the skin, giving rise to inflammatory lesions. Despite its distinctive clinical presentation, carcinoma erysipeloides may elude PET scan detection due to its subtle metabolic activity and superficial location, underscoring PET's limitations in identifying lymphatic metastases [14][15].

In summary, while PET scan serves as a valuable tool in breast cancer surveillance post-surgery, its efficacy in detecting lymphatic metastases is limited by the low metabolic activity of these lesions. The reliance of PET scan on glucose metabolism as a biomarker for malignancy may result in false-negative findings for lymphatic metastases, necessitating complementary imaging modalities and clinical evaluation for comprehensive disease assessment. Lymphatic metastases in cancer, including breast cancer, often manifest as small, subclinical lesions with lower metabolic rates compared to primary tumors or metastases in highly perfused organs. Thus, PET scans may overlook critical sites of disease progression, leading to false-negative results. To address this limitation and enhance cancer surveillance accuracy, several alternative or adjunctive imaging modalities can be considered. Magnetic resonance imaging (MRI) offers superior soft tissue contrast and spatial resolution.

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