RADIOLOGY OF IDC AFTER CHEMOTHERAPY: POST-TREATMENT IMAGING CHARACTERISTICS AND DIAGNOSTIC CHALLENGES

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Abstract. *Invasive ductal carcinoma (IDC) is the most common form of breast cancer, and chemotherapy—particularly neoadjuvant chemotherapy (NAC)—plays a crucial role in reducing tumor burden before surgery. Radiological imaging is essential for evaluating tumor response, detecting residual disease, and guiding further therapeutic decisions. This article reviews the radiologic features of IDC after chemotherapy across mammography, ultrasound, MRI, and emerging imaging modalities, highlighting their diagnostic value and limitations.*

Introduction

Neoadjuvant chemotherapy is widely used for patients with locally advanced IDC, HER2-positive tumors, triple-negative breast cancer, and cases where breast-conserving surgery is planned. Post-chemotherapy radiologic assessment provides vital information on tumor shrinkage, detection of residual malignancy, evaluation of treatment response, prediction of pathological complete response (pCR), and surgical planning.

2. Mammographic Features After Chemotherapy

2.1 Size Reduction and Density Changes

One of the most important radiological indicators used to evaluate the effectiveness of neoadjuvant chemotherapy (NAC) in patients with invasive ductal carcinoma (IDC) is the pattern of tumor size reduction and the associated changes in breast tissue density. Mammography, despite certain limitations, continues to play a central role in monitoring treatment response because of its ability to visualize structural changes in the breast parenchyma, stromal components, and residual tumor morphology.

After chemotherapy, the most common mammographic finding is a measurable decrease in the size of the primary tumor. This reduction, however, does not always occur uniformly. In some cases, IDC demonstrates a **concentric shrinkage pattern**, in which the tumor retracts symmetrically, leading to a smaller but morphologically similar lesion. This pattern is often associated with a better overall chemotherapeutic response. In other cases, particularly in heterogeneous or biologically aggressive tumors, shrinkage occurs in a **fragmented or scattered form**, where the mass appears irregular, discontinuous, or dispersed. This phenomenon results from chemotherapy-

induced tumor necrosis, stromal remodeling, and partial dissolution of malignant cell clusters.

In addition to changes in size, mammographic density alterations provide important clues regarding treatment response. Breast tissue surrounding the tumor often exhibits **decreased density** due to reductions in peritumoral edema, inflammatory infiltration, and vascular congestion. These changes reflect the diminished metabolic activity of the tumor and its surrounding microenvironment. The decreased density may also indicate the replacement of viable cancer cells with fibrotic tissue, which typically presents as a more radiopaque but structurally stable area [1,3,10].

Notably, the density reduction is not always proportional to the actual pathological response. In some patients, despite significant radiological decreases in density, residual microscopic disease may persist. Conversely, extensive fibrotic replacement can create the illusion of residual mass even when the malignant component has been largely eradicated. These findings highlight the biological complexity of tumor regression and the need for multimodal imaging [5,6].

Another significant aspect of post-chemotherapy density changes involves the alteration of the tumor margins. As the tumor responds to treatment, its borders often become less defined and more indistinct. This effect is related to stromal desmoplasia and the gradual loss of cohesive tumor architecture. The mammographic appearance of such lesions can shift from sharply circumscribed masses to **faint, ill-defined densities**, complicating the estimation of true tumor extent.

Fragmentation of the tumor is a particularly noteworthy mammographic phenomenon. Chemotherapy not only reduces tumor size but may also break it into multiple smaller residual foci. Some of these foci may be difficult to distinguish from benign post-treatment changes, such as fibrosis, fat necrosis, or microcystic alterations. In these cases, relying solely on mammographic findings can lead to an underestimation of the remaining tumor burden, making correlation with ultrasound or MRI essential.

Overall, the size and density changes seen on mammography after chemotherapy provide critical insight into the tumor's biological response. However, these radiological findings must be interpreted with caution, considering the variability in tumor biology, the potential masking effects of fibrosis, and the limitations of mammographic contrast resolution. In the broader context of IDC management, mammography serves as an important but not definitive tool, requiring integration with clinical examination, advanced imaging modalities, and pathological evaluation for the most accurate assessment of therapeutic effectiveness.

2.2 Calcification Patterns

Calcification patterns observed on mammography play a significant but often misunderstood role in assessing the response of invasive ductal carcinoma (IDC) to chemotherapy. While microcalcifications are traditionally associated with ductal carcinoma in situ (DCIS) and certain subtypes of IDC, their behavior after neoadjuvant chemotherapy (NAC) remains complex and at times paradoxical. Unlike tumor mass size or contrast enhancement, calcifications do not reliably correlate with the amount of residual viable cancer, which makes their interpretation particularly challenging in the post-treatment setting.

One of the most notable observations is that **microcalcifications may persist even when the tumor has undergone a complete pathological response (pCR)**. This persistence occurs because most calcifications represent **dystrophic deposits**, formed from necrotic debris, degenerating cellular structures, or prior ductal injury—elements that do not necessarily disappear with chemotherapy. These calcifications, therefore, often act as a historical "footprint" of the original tumor rather than a marker of ongoing malignancy. When a tumor responds well to chemotherapy, the viable cellular component may shrink dramatically, but the calcified remnants embedded within the stromal matrix can remain radiographically visible.

In other cases, microcalcifications may appear **more fragmented, coarser, or altered in distribution** following chemotherapy. This change reflects the biochemical remodeling of the tumor microenvironment. As malignant cells undergo apoptosis or necrosis, the structural architecture collapses, and calcified deposits may break apart or shift position. While such fragmentation may suggest treatment effect, it does not definitively prove tumor eradication. Residual carcinoma foci can still persist between calcified clusters, underscoring the need for complementary imaging techniques and biopsy confirmation.

Another important point is that calcifications may appear **unchanged** on mammography even when chemotherapy has significantly reduced the invasive tumor burden. This stability further complicates the assessment of treatment response. Radiologists must therefore exercise caution in assuming that persistent calcifications indicate persistent disease. In many patients, the calcifications reflect a combination of pre-treatment tumor biology and post-treatment scarring rather than ongoing malignancy.

Conversely, in a smaller subset of patients, **new or increasing calcifications** may be detected after chemotherapy. This phenomenon may initially raise concern for progression; however, it is often related to **treatment-induced necrosis** rather than tumor regrowth. The breakdown of malignant tissue releases calcium ions into the surrounding stroma, where they may precipitate into newly formed dystrophic calcifications. This process highlights the dynamic interplay between therapy, tumor biology, and tissue response [10].

Given these complexities, calcification patterns alone do not reliably predict tumor viability. Their presence or appearance must always be interpreted within a broader diagnostic context that includes tumor mass assessment, enhancement characteristics on MRI, ultrasound findings, and clinical examination. In many cases, MRI remains more sensitive for detecting residual viable tumor, while mammographic calcifications serve as supplementary, rather than definitive, indicators.

Ultimately, the evaluation of calcification patterns after chemotherapy requires a nuanced understanding of both pathological processes and imaging limitations. While calcifications provide valuable historical insight into tumor behavior, they cannot be relied upon as sole markers of therapeutic effectiveness. Integrated diagnostic approaches remain essential for accurately determining residual disease and guiding optimal surgical and oncologic management.

3. Ultrasonography Findings After Chemotherapy

Ultrasound commonly shows smaller hypoechoic masses, irregular margins, decreased vascularity, and increased posterior acoustic shadowing due to fibrosis. Elastography helps differentiate residual malignancy from fibrosis based on tissue stiffness.

4. Magnetic Resonance Imaging (MRI)

MRI is the most accurate modality for post-chemotherapy evaluation. It identifies reduction in tumor size, architectural distortion, and changes in enhancement kinetics. DCE-MRI shows reduced enhancement in responders, whereas DWI reveals increased ADC values following effective therapy.

5. Radiologic–Pathologic Correlation

Imaging may differ from pathology due to chemotherapy-induced necrosis, fibrosis, or scattered tumor cells. MRI correlates most accurately with histopathology.

6. Imaging of Subtypes

Triple-negative and HER2-positive IDC typically show strong radiologic response. Luminal types respond less and may show persistent enhancement due to fibrosis.

7. Challenges

Distinguishing fibrosis from residual tumor, persistent calcifications, and under- or overestimation of tumor size are common challenges.

8. Future Directions

AI, radiomics, PET/MRI, and advanced ultrasound techniques may greatly improve accuracy and treatment personalization.

Conclusion

Radiologic assessment of IDC after chemotherapy is essential in evaluating treatment outcomes and guiding surgical decisions. MRI remains the most sensitive tool, while multimodal imaging offers the highest diagnostic accuracy.

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