Exploring the Role of PET-CT in Radiotherapy Planning: Insights from Clinical Experience

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ABSTRACT

Radiotherapy is a cornerstone of cancer treatment, benefiting nearly 50% of patients during their disease journey. Despite its efficacy, traditional imaging modalities like contrast-enhanced computed tomography (CT) face limitations in accurately delineating tumors and identifying metastatic spread, which is crucial for effective radiotherapy planning. This study explores the impact of integrating Positron Emission Tomography and Computed Tomography (PET-CT) in radiotherapy planning compared to CT alone, particularly in resource-limited settings like Bangladesh. PET-CT, by providing molecular-level insights through tracers such as 2-fluoro-2-deoxyglucose (18F-FDG), offers superior tumor visualization and metabolic assessment. Two case studies highlight the clinical significance of PET-CT-based planning in radiotherapy. In the case of non-small cell lung cancer (NSCLC), PET-CT revealed previously undetected metastases, prompting a shift from radiotherapy to systemic chemotherapy, thus avoiding inappropriate treatment. In another case involving male breast carcinoma, PET-CT resolved uncertainties in tumor localization, enabling precise delineation and dose adjustments for effective radiotherapy. Both cases underscore PET-CT's ability to refine treatment strategies, enhance diagnostic accuracy, and improve therapeutic outcomes. While CT remains widely accessible, its limitations highlight the need for complementary imaging. PET-CT bridges this gap, improving tumor staging, delineation, and treatment adaptation. However, challenges such as cost and accessibility hinder its widespread adoption in resource-constrained regions. This study emphasizes the transformative potential of PET-CT in radiotherapy workflows, advocating for its integration to enhance treatment precision and optimize oncological care in low-resource settings.

Keywords: Radiotherapy, PET/CT, tumor delineation, 18F-FDG, NSCLC, male breast carcinoma, resource-limited settings, oncology.

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INTRODUCTION

Radiotherapy is a cornerstone in the clinical management of oncological diseases, providing therapeutic benefits to approximately 50% of cancer patients during their treatment journey. This therapeutic method can be used independently or as part of a multidisciplinary treatment plan (1). Depending on the therapy setting, it can provide both localized and systemic advantages, making it an important component of oncological care. With integrative approaches and technology advancements in cancer treatment, its role keeps growing, highlighting how crucial it is to enhancing patient outcomes (2). The total effectiveness of the cancer management protocol is increased when radiotherapy is paired with systemic medicines like chemotherapy or targeted medication therapy in a comprehensive treatment plan. Chemotherapy can make tumors more vulnerable to the effects of radiation by sensitizing them to it. Modern radiotherapy innovations, including proton therapy, stereotactic body radiation (SBRT), and intensity-modulated radiation therapy (IMRT), have greatly increased treatment accuracy and efficacy. (3,4).

Target volumes for radiation are commonly defined in clinical practice using sophisticated anatomic imaging modalities such as magnetic resonance imaging (MRI) and contrast-enhanced computed tomography (CT). These imaging methods enable accurate treatment planning by providing comprehensive structural and geographic information about tumors. Accurately defining live tumor tissue, however, is frequently difficult, particularly when patients have had previous therapies like surgery. Because surgical procedures can change the local anatomy, it can be challenging to identify the difference between postoperative changes and remaining tumor tissue. The conventional imaging method for scheduling three-dimensional conformal radiation (3D-CRT), contrast-enhanced computed tomography (CT), has poor sensitivity and specificity for precisely determining the size of primary tumors and nodal involvement (5,6).

These restrictions have a big impact on how target quantities are defined. The accuracy of determining the gross tumor volume (GTV) and its subsequent extension into the planned target volume (PTV) can be increased by adding other imaging modalities to CT.

In the management of cancer patients receiving radiation therapy, positron emission tomography (PET) imaging is becoming more and more important. PET imaging offers molecular-level insights that enable the visualization and measurement of crucial tumour properties including metabolism and receptor expression, in contrast to traditional imaging techniques that concentrate on anatomical aspects. PET is a vital technique for accurately evaluating tumors because of its functional imaging capabilities, especially when structural imaging alone may not be enough (7, 8). The most widely used PET tracer in oncology is fluorodeoxyglucose (18F-FDG), a glucose analog. Its popularity stems from its ability to map glucose metabolism, a hallmark of many cancers, and its growing accessibility across healthcare facilities (9). By highlighting areas of increased metabolic activity, 18F-FDG PET plays a crucial role in tumor detection, staging, and treatment planning. Moreover, it aids in monitoring treatment response and differentiating between tumor recurrence and post-treatment changes, such as inflammation or necrosis.

The objective of this study is to evaluate the impact of PET-based radiotherapy planning compared to CT-based planning in the management of cancer patients in Bangladesh. By highlighting the advantages of PET-CT in terms of accurate tumor delineation, detection of metastases, and improved treatment precision, this study aims to underscore its potential to enhance patient outcomes in a resource-constrained healthcare setting like Bangladesh, where late diagnosis and limited access to advanced technologies remain significant challenges.

Case-1

Patient Background and Clinical Presentation

A male patient aged 59, had been experiencing severe weight loss for two months, chest pain, and a persistent cough. The diagnosis of non-small cell lung cancer (NSCLC) was confirmed by a comprehensive diagnostic workup that included imaging and biopsy. To control the localized disease, the treating oncologist suggested radiotherapy as the main treatment option after the diagnosis.

CT and PET-Based Radiotherapy Planning

To define the tumour and establish the radiation target volumes, CT-based radiotherapy planning was carried out before treatment began.

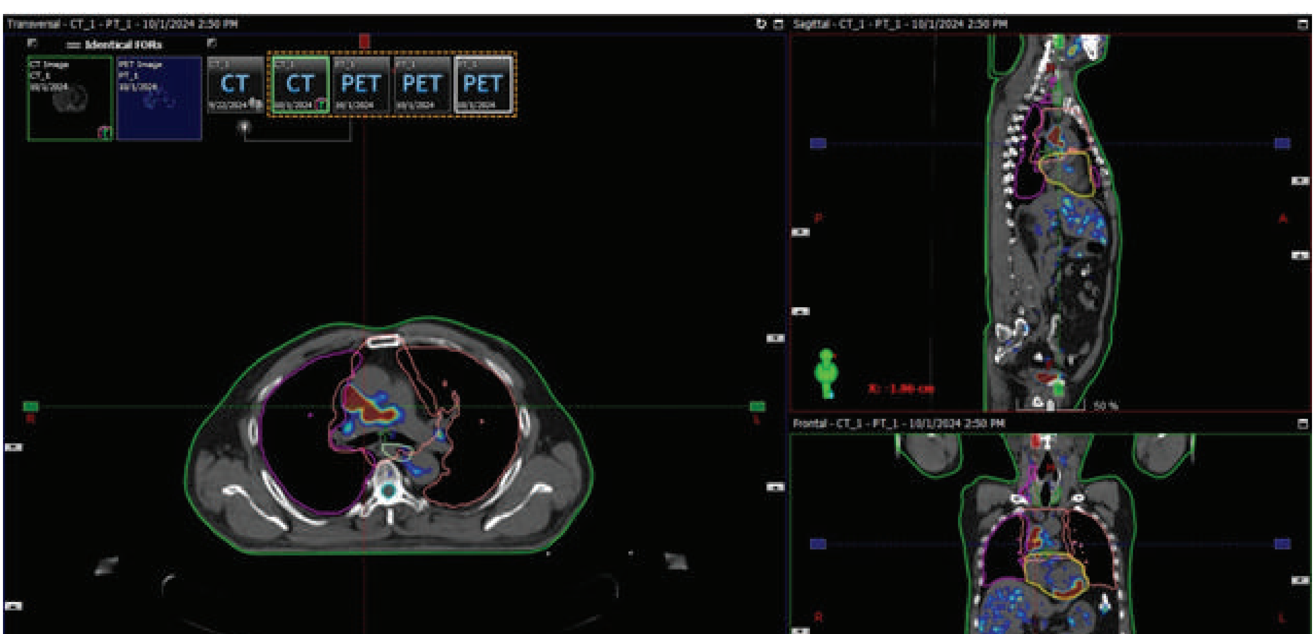

Figure 1: CT-Based Radiotherapy Treatment Planning

The CT scans showed a lump in the lung's right upper lobe, but it was hard to determine the tumor's exact location or whether it had spread to nearby structures. Additionally, CT imaging created uncertainty in planning due to its inadequacies in distinguishing between benign or inflammatory alterations and malignant tumours, which heightened concerns about possible metastases. To resolve these uncertainties, PET/CT imaging was performed. The lymph node metastases in the hilar, paratracheal region of the right lung were readily identified by the PET/CT scans, which also offered morphological and metabolic insights. These results verified the existence of more lymph node metastases than expected, altering the clinical staging and necessitating the inclusion of additional regions in the planning of radiation. A more accurate evaluation was ensured by PET/CT, which provided better tumour boundary delineation and correctly distinguished malignant lesions from benign or inflammatory alterations.

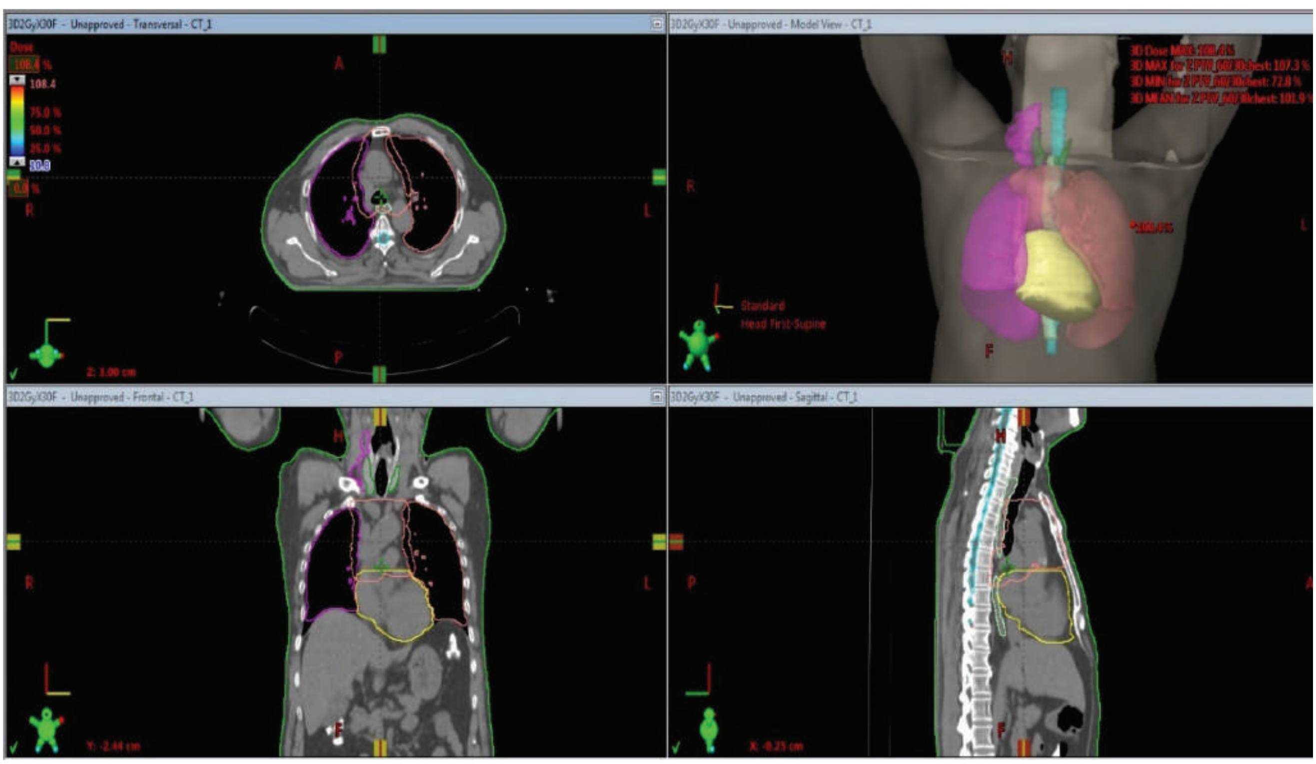

Figure 2: PET-based Radiotherapy treatment planning Changes in Radiotherapy Dose and Outcome

The radiation area was revised in light of the PET/CT results to provide the best possible coverage of the tumour while limiting exposure to nearby healthy tissues. An efficient treatment plan catered to the patient's unique tumour features resulted from the modified treatment area. Better targeting, a lower chance of undertreatment, and a higher chance of therapeutic success were all made possible by the precise tumour position delineation provided by PET-CT. The benefits of PET-CT over CT in radiation planning for non-small cell lung cancer are demonstrated by this case study. Radiotherapy precision may be impacted by CT's limits in tumour localization, despite the fact that it offers useful anatomical information. By integrating metabolic and anatomical imaging, PET-CT improves tumour delineation accuracy, permits adaptive dose modifications, and eventually results in better patient outcomes. This case emphasizes how crucial it is to include PET-CT in normal radiation planning, especially when dealing with complicated anatomical issues.

Case 2

Patient Background and Clinical Presentation

A 70-year-old male presented with a palpable lump in his left breast, some minor edema, and some discomfort.

The diagnosis of infiltrating ductal carcinoma (Grade II), a rare but important condition in men, was confirmed by a diagnostic workup that included mammography and biopsy. Radiotherapy was suggested as part of the treatment plan because of the advanced stage of the disease and following the operation.

CT and PET Based Radiotherapy Planning

To locate the tumour and define the treatment region, preliminary CT-based planning was carried out. However, the precise location of the tumour in relation to the chest wall and surrounding tissues was not readily visible on CT imaging. Because of this uncertainty, it was difficult to calculate doses accurately and preserve healthy tissue. Using PET-CT imaging, these uncertainties were addressed. The tumour in the right hilar region was effectively located by PET-CT, which showed advanced illness. As a result, the patient's stage was modified from localized to advanced, making them ineligible to receive radiation therapy.

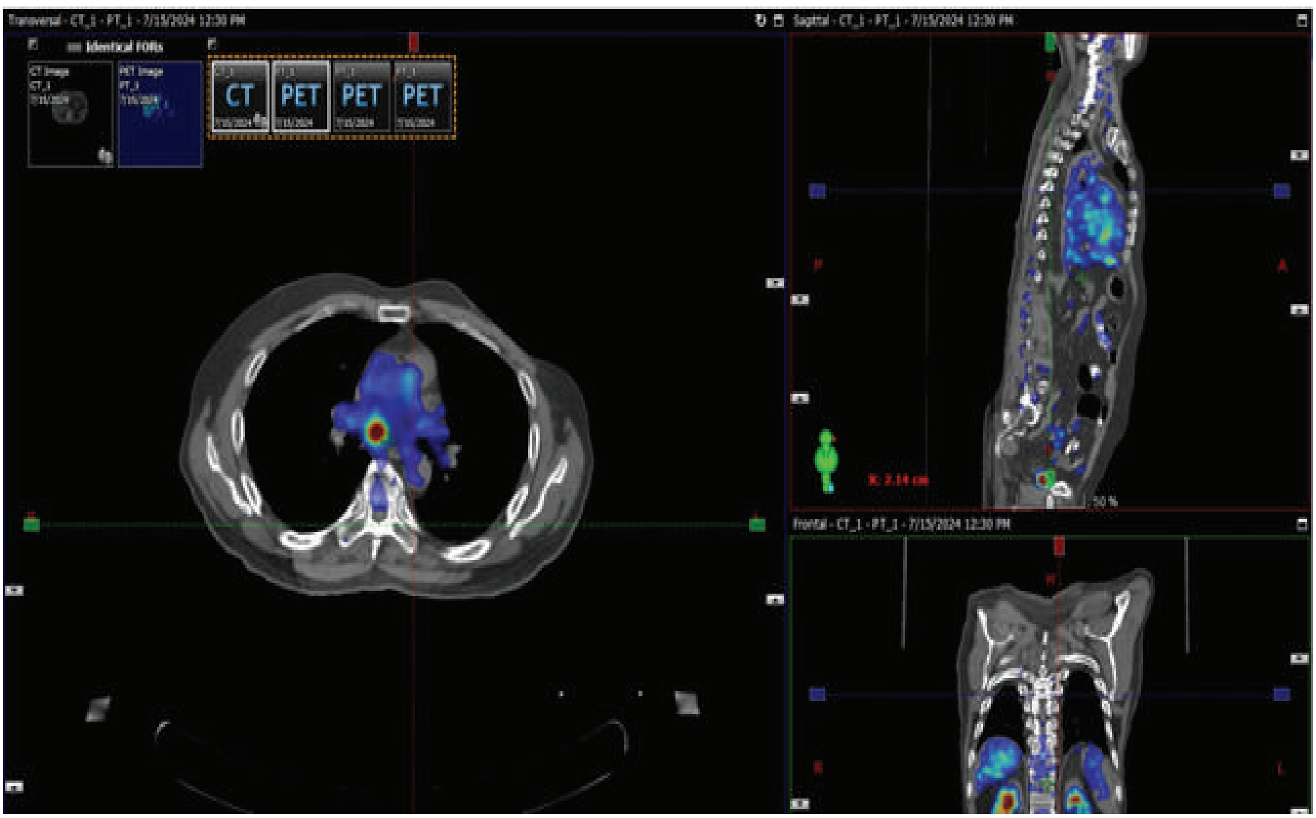

Figure 3: PET- CT image showing Right-Sided Hilar Lymph Node Metastasis.

Clinical Decision and Outcome

The treatment plan was greatly altered by the PET-CT findings. Radiotherapy was no longer regarded as suitable after the metastatic illness was confirmed. Rather, systemic chemotherapy—the recommended treatment for advanced-stage infiltrating breast cancer—was recommended, and the patient was sent back to the doctor. In addition to avoiding needless radiation, this change in treatment method optimized the therapeutic approach by taking into account the patient's current state of illness. This case emphasizes how important PET-CT is when planning radiation therapy for breast cancer. While CT is still widely used because it is accessible and affordable, the incorporation of PET-CT into radiotherapy planning, especially in resource-constrained settings like Bangladesh, could greatly improve treatment precision and patient outcomes. PET-CT improves diagnostic accuracy, improves tumour delineation, and detects metastatic spread. In this patient, PET-CT-based planning prevented an inappropriate treatment decision, demonstrating its value in changing clinical management and ensuring optimal care.

DISCUSSION

Patient outcomes and treatment accuracy are much improved when PET-CT is incorporated into radiation planning, as the cases described demonstrate. In the first instance of non-small cell lung cancer (NSCLC), PET-CT eliminated CT-observed uncertainties in tumor localization, allowing for accurate tumor delineation and radiation dose recalibration to maximize coverage while minimizing harm to healthy tissues, leading to an expansion of the treatment planning area (10). In the second case involving male breast carcinoma, PET-CT identified right-sided hilar lymph node metastases undetected by CT, making it an advanced disease, making a shift from radiotherapy to systemic chemotherapy, thereby avoiding unnecessary radiation exposure and aligning the treatment with the advanced disease stage (9, 10). These results highlight the enhanced diagnostic potential of PET-CT, which offers anatomical and metabolic information that enhances tumor delineation, staging precision, and treatment adaptation. Although CT is frequently used because it is affordable and accessible, its shortcomings in reliably identifying tumor boundaries and detecting metastatic spread underscore the significance of complementing imaging modalities (11, 12). Although PET-CT faces challenges such as higher costs and limited availability in resource-constrained settings like Bangladesh, its ability to tailor treatment to precise disease characteristics justifies its integration into routine oncological practice (9, 10, 11).

CONCLUSION

This study highlights the transformative role of PET-CT in radiotherapy planning, particularly in resource-constrained settings like Bangladesh. By offering superior diagnostic accuracy in tumor delineation and metastatic detection, PET-CT addresses the key limitations of conventional CT imaging. The two presented cases demonstrate PET-CT's ability to refine treatment decisions, avoiding unnecessary radiotherapy in metastatic male left breast carcinoma and enabling precise tumor localization and dose adjustment in non-small cell lung cancer (NSCLC). These findings underscore the critical value of integrating PET-CT into radiotherapy workflows to improve treatment precision, optimize resource utilization, and enhance patient outcomes. Despite challenges such as higher costs and limited accessibility, the clinical benefits of PET-CT in ensuring evidence-based, individualized cancer care strongly advocate for its wider adoption in oncology practices.

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