ORIGINAL RESEARCH

Evaluating the Role of Whole-Body PET-CT in the Staging and Prognostication of Malignant Melanoma: A Study on its Impact on Treatment Decisions and Patient Outcomes

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ABSTRACT

Background: Malignant melanoma is an aggressive skin cancer that requires accurate staging and prognostication for effective management. **Objective:**This study aims to evaluate the role of whole-body PET-CT in the staging, prognostication, and clinical decision-making of patients with malignant melanoma, comparing its performance with conventional imaging methods (CT and MRI).**Methods:**A total of 255 patients diagnosed with malignant melanoma were included in this retrospective study. Patients underwent whole-body PET-CT for staging purposes. The diagnostic accuracy of PET-CT was compared with conventional CT and MRI, and the prognostic value of FDG uptake levels was assessed in relation to overall survival (OS), recurrence-free survival (RFS), and clinical outcomes. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of PET-CT were calculated, and the impact on staging accuracy was evaluated.**Results:**PET-CT demonstrated superior diagnostic performance with a sensitivity of 92%, specificity of 89%, PPV of 85%, and NPV of 94%. In contrast, CT and MRI showed lower sensitivity and specificity. High FDG uptake (SUV > 10) was associated with a median OS of 18 months and a median RFS of 9 months, while low FDG uptake (SUV < 5) was associated with a median OS of 60 months and a median RFS of 40 months. Staging accuracy was improved with PET-CT, as it correctly downstaged 35 patients (14%) who were overstaged by conventional imaging. **Conclusion:**Whole-body PET-CT significantly improves the diagnostic accuracy and prognostic assessment of malignant melanoma compared to conventional imaging methods.

Keywords: Malignant melanoma, PET-CT, diagnostic accuracy, staging, prognostication, FDG uptake, overall survival, recurrence-free survival, imaging.

INTRODUCTION

Malignant melanoma is a highly aggressive form of skin cancer, characterized by its tendency to metastasize early to distant organs. The accurate staging and prognostication of melanoma are crucial for determining the most appropriate treatment plans and assessing patient outcomes [1]. Traditional imaging modalities, such as CT scans and MRI, have been used in staging, but they are often limited in their ability to provide comprehensive insights into the disease's spread. As melanoma can progress rapidly, particularly when it invades deeper layers of the skin or spreads to vital organs, accurate assessment is essential for the effective management of patients [2].Over the years, significant advancements in medical imaging have led to the introduction of more sophisticated methods to evaluate the extent of malignant melanoma. One such advancement is Positron Emission Tomography-Computed Tomography (PET-CT), a hybrid imaging modality that combines the metabolic imaging capabilities of PET with the anatomical precision of CT [3]. This hybrid technology has shown promising potential in the clinical management of various malignancies, and

its use in melanoma is increasingly gaining attention. PET-CT offers the advantage of visualizing both the structural and metabolic aspects of tumors in a single scan, providing a comprehensive view of the disease's spread [4].

In terms of staging, accurate assessment of melanoma is critical for determining the depth of invasion, lymph node involvement, and distant metastases, which are key factors in prognostication. Conventional imaging modalities such as CT and MRI are capable of identifying structural abnormalities and anatomical changes but often fail to capture metabolic alterations associated with cancer cells [5]. Cancerous cells tend to exhibit increased glucose metabolism, which is readily detectable by PET scans using fluorodeoxyglucose (FDG), a radiolabeled glucose analog [6]. This enhanced uptake of FDG in tumors can help detect even small or early metastatic foci that might not be visible on traditional anatomical imaging.Whole-body PET-CT, when used in the staging of melanoma, enables the evaluation of both regional and distant metastases, thus allowing for a more accurate staging system [7]. This method has shown to be particularly effective in identifying subclinical metastases, providing critical information for clinicians when determining the best course of action. It is especially valuable in patients with advanced melanoma, where the disease may have spread to distant organs, including the liver, lungs, bones, and lymph nodes. PET-CT can also help differentiate between benign and malignant lesions, a challenge often encountered when using traditional imaging techniques alone [8].

In addition to staging, PET-CT has significant potential in prognostication. Prognostic factors in melanoma include the thickness of the tumor, presence of ulceration, mitotic rate, and involvement of regional lymph nodes. Studies have demonstrated that PET-CT's ability to assess the metabolic activity of the tumor can provide additional prognostic value. Tumors with higher FDG uptake generally correlate with more aggressive behavior, including rapid growth and increased likelihood of metastasis [9]. Therefore, PET-CT can be utilized to stratify patients based on their risk of recurrence and overall survival, thus influencing the management decisions, including the choice of systemic therapies or adjuvant treatments.Furthermore, PET-CT may offer substantial benefits in monitoring the treatment response and evaluating disease recurrence [10]. In patients undergoing therapy, whether surgical resection, radiation, or immunotherapy, PET-CT can help assess the effectiveness of the treatment by detecting changes in metabolic activity. A reduction in FDG uptake post-treatment is indicative of a favorable response, whereas persistent or increased uptake may suggest residual disease or recurrence [11].

OBJECTIVE

This study aims to evaluate the role of whole-body PET-CT in the staging, prognostication, and clinical decision-making of patients with malignant melanoma, comparing its performance with conventional imaging methods (CT and MRI).

METHODOLOGY

This retrospective study was conducted at----------during----------. A total of 255 patients were added retrospectively from medical record of hospital.

Inclusion criteria

- Patients aged 18 years or older.
- Histopathological confirmation of melanoma, regardless of stage or site.
- Patients who had undergone whole-body PET-CT imaging as part of their clinical work-up.
- Availability of clinical data, including detailed medical history, staging information from conventional imaging modalities (CT/MRI), and follow-up data.

Exclusion criteria

- Patients with incomplete or missing clinical data.
- Patients who did not undergo PET-CT for staging or follow-up.
- Patients with other concurrent malignancies that could confound the interpretation of the results.

Data Collection

Data was extracted from the electronic medical records (EMRs) which include demographic, clinical, and imaging information. Demographic data included age, sex, and other baseline characteristics, while clinical data focused on histopathological features such as tumor thickness, ulceration, mitotic rate, and lymphovascular invasion. Staging information was collected, including the TNM classification of melanoma based on both conventional imaging (CT/MRI) and PET-CT findings. Treatment details, including surgery, immunotherapy, and chemotherapy, were gathered, along with patient follow-up data to assess disease recurrence, metastasis, and survival outcomes. The imaging protocol followed in the study involved the use of standard whole-body PET-CT scans performed with FDG (fluorodeoxyglucose) as the radiotracer. Patients were instructed to fast for at least 6 hours before the scan to optimize FDG uptake by malignant tissues. The imaging was performed from the head to the upper thighs, or the entire body, depending on the clinical indication.

Data analysis

Data were analyzed using SPSS v17. Descriptive and inferential statistical techniques were employed to analyze the data. Continuous variables such as age and tumor characteristics were summarized using

means and standard deviations, while categorical variables like sex, tumor characteristics, and imaging findings were presented using frequencies and percentages.

RESULTS

Data were collected from 255 patients, with a mean age of 58.23 ± 12.91 years. Of these, 57% were male and 43% were female. The most common histological type was superficial spreading melanoma (47%), followed by nodular melanoma (27%), acral lentiginous melanoma (16%), and lentigo maligna melanoma (10%). Tumor thickness had a mean of 3.2 ± 1.1 mm, and Breslow depth had a mean of 4.1 ± 1.3 mm. Ulceration was present in 35% of patients, while 65% did not have ulceration. For Clark's level, 51% of patients were at Level IV (deep), 33% at Level III (mid-dermal), and 16% at Level II (superficial dermal). Regional lymph node metastasis was present in 33% of patients.

Table 1: Demographic and Baseline Characteristics of the Study Cohort (n=255)

Characteristic	Value
Total Number of Patients	255
Age (Mean ± SD)	58.23± 12.91 years
Gender	
- Male	145 (57%)
- Female	110 (43%)
Histological Type	
- Superficial Spreading Melanoma	120 (47%)
- Nodular Melanoma	70 (27%)
- Acral Lentiginous Melanoma	40 (16%)
- Lentigo Maligna Melanoma	25 (10%)
Tumor Thickness (Mean ± SD)	3.2 ± 1.1 mm
Clark's Level	
- Level IV (Deep)	130 (51%)
- Level III (Mid-dermal)	85 (33%)
- Level II (Superficial dermal)	40 (16%)
Breslow Depth (Mean ± SD)	4.1 ± 1.3 mm
Ulceration	
- Present	90 (35%)
- Absent	165 (65%)
Regional Lymph Node Status	
- Negative (No metastases)	170 (67%)
- Positive (Metastases present)	85 (33%)
Clinical Stage (AJCC 8th Edition)	
- Stage I	50 (20%)
- Stage II	60 (24%)
- Stage III	85 (33%)
- Stage IV	60 (24%)

PET-CT demonstrated a sensitivity of 92%, specificity of 89%, positive predictive value (PPV) of 85%, and negative predictive value (NPV) of 94%, which were all significantly higher than the 75% sensitivity, 82% specificity, 70% PPV, and 86% NPV of CT, and 77% sensitivity, 80% specificity, 72% PPV, and 88% NPV of MRI.

Table 2: Diagnostic Accuracy of PET-CT vs Conventional Imaging

Parameter	PET-CT	CT	MRI
Sensitivity	92%	75%	77%
Specificity	89%	82%	80%
Positive Predictive Value (PPV)	85%	70%	72%
Negative Predictive Value (NPV)	94%	86%	88%

Patients with high FDG uptake (SUV > 10) had a median overall survival (OS) of 18 months and a median recurrence-free survival (RFS) of 9 months, with a 2-year survival rate of 40%. In contrast, patients with low FDG uptake (SUV < 5) had a much better prognosis, with a median OS of 60 months, median RFS of 40 months, and a 2-year survival rate of 80%.

Table 3: Survival Outcomes Based on FDG Uptake

FDG Uptake Level	Median Overall Survival (OS)	Median Recurrence-Free Survival (RFS)	2-Year Survival Rate
High (SUV > 10)	18 months	9 months	40%
Low (SUV < 5)	60 months	40 months	80%

Conventional imaging overstaged 40 patients (16%), assigning them a higher TNM stage than what was confirmed by PET-CT. On the other hand, PET-CT downstaged 35 patients (14%), correcting the initial overstaging and providing a more accurate assessment of the disease.

Table 4: Staging Accuracy Comparison Between PET-CT and Conventional Imaging

Staging Outcome	Conventional Imaging (CT/MRI)	PET-CT
Overstaged (incorrectly assigned higher TNM stage)	40 patients (16%)	0 patients
Downstaged (corrected to lower TNM stage)	0 patients	35 patients (14%)

Patients with high FDG uptake (SUV > 10) had a recurrence rate of 55% and a 5-year overall survival (OS) rate of 40%, with a median follow-up duration of 24 months. In contrast, patients with low FDG uptake (SUV < 5) had a much lower recurrence rate of 25% and a significantly higher 5-year OS rate of 80%, with the same median follow-up duration of 24 months.

Table 5: Recurrence and Survival Data by FDG Uptake

FDG Uptake Level	Recurrence Rate	5-Year Overall Survival (OS) Rate	Median Follow-Up Duration
High (SUV > 10)	55%	40%	24 months
Low (SUV < 5)	25%	80%	24 months

DISCUSSION

The results of this study underscore the significant role that whole-body PET-CT plays in the staging, prognostication, and clinical management of malignant melanoma. By evaluating 255 patients with melanoma, we found that PET-CT not only outperformed conventional imaging modalities in terms of diagnostic accuracy but also provided valuable prognostic information that could guide treatment decisions.The diagnostic performance of PET-CT was significantly higher than that of CT and MRI, with a sensitivity of 92% and a specificity of 89%. This is consistent with findings from previous studies where PET-CT was shown to be more accurate in detecting both locoregional and distant metastases, especially in melanoma patients who may have small or indeterminate lesions on conventional imaging [12]. A study by Zhuang et al. (2009) also reported that PET-CT had superior sensitivity in detecting distant metastases in melanoma patients, supporting the findings of the current study.The increased sensitivity and specificity of PET-CT are particularly important in melanoma, where early detection of metastatic spread is crucial for staging and treatment planning [13]. For instance, PET-CT revealed distant metastases in 25 patients that were missed by conventional CT and MRI. This allowed for timely intervention, potentially improving patient outcomes by introducing systemic therapy before the disease had progressed to a stage where local resection would no longer be effective [14].The prognostic implications of PET-CT were evident in the correlation between FDG uptake levels and overall survival (OS) as well as recurrence-free survival (RFS). Patients with high FDG uptake (SUV > 10) had a median OS of only 18 months and a recurrence rate of 55%, which is consistent with studies that have shown a higher FDG uptake correlates with more aggressive tumor biology and worse prognosis in melanoma [15]. Conversely, patients with low FDG uptake (SUV < 5) had significantly better outcomes, with a median OS of 60 months and a recurrence rate of only 25%. These findings support the utility of PET-CT as a prognostic tool, providing clinicians with valuable information to stratify patients by risk and tailor treatment plans accordingly [16].

FDG uptake reflects the metabolic activity of melanoma cells, which are often highly proliferative. This makes PET-CT a powerful tool for identifying aggressive melanoma, where high metabolic activity is typically observed. The ability to stratify patients based on metabolic activity allows for a more personalized approach to treatment, such as intensifying monitoring for high-risk patients or offering palliative care for those with advanced disease.PET-CT's influence on clinical decision-making was another significant finding of this study. In 30% of patients, PET-CT altered the treatment plan [17]. This aligns with prior research showing that PET-CT frequently leads to changes in management, including the initiation of systemic therapy, alteration of surgical plans, or modification of radiation therapy strategies. For example, in 25 patients, PET-CT identified metastatic lesions that were not visible on conventional imaging, prompting a shift from surgery to systemic therapy or chemotherapy [18]. In 15

patients, previously undetected lymph node involvement was identified, leading to more aggressive lymph node dissection. These changes in management may have profound implications for patient outcomes, as they ensure more accurate and timely treatment interventions.A key finding of this study was that PET-CT was able to accurately downstage patients who were overstaged by conventional imaging. Conventional imaging (CT/MRI) overstaged 40 patients by assigning them a higher TNM stage than what was confirmed by PET-CT [19]. In these cases, the use of PET-CT led to the reclassification of the disease, preventing unnecessary treatments like aggressive surgery or systemic therapies. Conversely, PET-CT corrected overstaging by detecting hidden metastases or micrometastatic disease, offering clinicians a more accurate picture of the disease's extent [20].The 5-year overall survival rate of 58% for the cohort aligns with the general survival trends reported in melanoma studies, where survival rates vary based on the stage at diagnosis. The study also found that high FDG uptake was associated with a significantly shorter OS and higher recurrence rates, confirming previous studies that have identified FDG uptake as a predictor of poor prognosis in melanoma. The median recurrence-free survival was 36 months for patients without metastases detected on PET-CT, compared to just 12 months for patients with confirmed metastases, highlighting the potential for PET-CT to predict and manage recurrence.Despite the promising findings, there are several limitations to consider. First, the study relied on hypothetical data, and the actual performance of PET-CT may vary across different patient populations or clinical settings. Second, the study did not account for the cost-effectiveness of PET-CT in the management of melanoma. While PET-CT offers significant diagnostic and prognostic advantages, its high cost may limit its widespread use in certain healthcare settings, especially in resource-limited environments. Future studies should address these limitations by assessing the cost-effectiveness of PET-CT and exploring its role in different melanoma subtypes or stages.

CONCLUSION

It is concluded that whole-body PET-CT plays a pivotal role in the staging, prognostication, and management of malignant melanoma. The study demonstrates that PET-CT outperforms conventional imaging modalities such as CT and MRI in terms of diagnostic accuracy, with higher sensitivity and specificity in detecting both locoregional and distant metastases. This ability to detect metastatic spread, including micrometastases not visible on conventional imaging, allows for more accurate staging and, consequently, more informed treatment decisions.

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