Impact of $^{18}$F-FDG-PET/CT on Staging and Irradiation of Patients with Locally Advanced Rectal Cancer

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Purpose: To investigate the impact of fluorodeoxyglucose-positron emission tomography/computed tomography (FDG-PET/CT) on planning of neoadjuvant radiotherapy for locally advanced rectal cancer (LARC) patients.

Patients and Methods: From January 2003 to December 2007, a total of 36 patients with LARC underwent a retrospective PET/CT study for radiotherapy-planning purposes. Gross tumor volume (GTV), clinical target volume (CTV) and planning target volume (PTV) were defined in a retrospective analysis by a blinded reader. The hypothetical boost volume was defined primarily on CT alone, and afterwards on the fused PET/CT dataset. The CT- and PET/CT-based GTVs were quantitatively compared and percentage of overlap (OV%) was calculated and analyzed. The impact of PET/CT on radiation treatment planning and overall patient management was evaluated.

Results: PET/CT-GTVs were smaller than CT-GTVs ($p < 0.05$). PET/CT imaging resulted in a change of overall management for three patients (8%). In 16 of 35 patients (46%), PET/CT resulted in a need for modification of the usual target volumes (CT-PTV) because of detection of a geographic miss.

Conclusion: FDG-PET/CT had significant impact on radiotherapy planning and overall treatment of patients with LARC.

Key Words: FDG · PET/CT · Rectal cancer · Radiotherapy

Introduction
Colorectal cancer is the third most common cancer worldwide [22]. The management of localized rectal cancer has significantly improved in the last years and today requires a multidisciplinary approach. After the introduction of a standardized surgical technique, the so-called total mesorectal excision, consistently low local recurrence rates were reported [20]. Recent studies have highlighted the central role of...
Radiation therapy associated with surgery to optimize local control, especially in locally advanced rectal cancer (LARC).

Neoadjuvant radiochemotherapy (RCT) is considered to be the standard treatment of LARC [35, 37, 40]. For patients in whom the circumferential resection margin is at risk or sphincter preservation is an issue, short-term radiation therapy (e.g., 5 × 5 Gy/week) cannot be recommended because it does not induce downstaging. Long-term RCT can downstage LARC, increasing the rate of complete surgical resection, allowing more frequent sphincter-sparing surgery, reducing toxicity, and improving pelvic control. The increased utilization of preoperative RCT results in the need of most accurate pretherpay imaging [9, 31].

¹⁸F-fluorodeoxyglucose-positron emission tomography/computed tomography (FDG-PET/CT) is an established imaging procedure in suspected recurrent colorectal cancer [10]. It has more rarely been used as an imaging tool for preoperative staging and radiation treatment planning in this setting. Only a few published studies evaluated PET/CT in the management of primary rectal tumors. Initial data suggest that PET/CT has a potential to detect metastatic disease or disease outside standard radiation fields and may alter clinical outcomes through more appropriate selection of treatment strategies [1, 8].

In this study, we investigated the clinical impact of ¹⁸F-FDG-PET/CT on staging, management decisions and radiotherapy planning of patients with LARC.

**Patients and Methods**

**Patient Selection**

We retrospectively identified patients with LARC who had been referred for neoadjuvant RCT and who underwent a PET/CT scan for radiotherapy planning purposes between January 2003 and December 2007.

All patients enrolled in the present study had a biopsy-proven rectal adenocarcinoma and were considered candidates for radiotherapy in a preoperative setting. Pretreatment staging was performed by rectoscopy, endoluminal ultrasound (EUS) and liver ultrasound, colonoscopy, chest X-ray, and PET/CT. Pelvic CT and MRI (magnetic resonance imaging) (EUS) and liver ultrasound, colonoscopy, chest X-ray, and staging was performed by rectoscopy, endoluminal ultrasound (EUS) and liver ultrasound, colonoscopy, chest X-ray, and PET/CT. Pelvic CT and MRI (magnetic resonance imaging) before PET/CT was not performed routinely.

Lymph nodes were considered positive if their diameter exceeded 1 cm on CT, if they were enlarged and/or had features of malignancy on transrectal ultrasound and/or on PET/CT.

Patients with clinical T3–4 or N+ tumors involving the rectal wall in the endoscopic segment from 0 to 15 cm were enrolled.

**PET/CT**

A PET/CT scanner with LSO crystals and a 16-slice CT component was used (Biograph Sensation 16®, Siemens Medical Solutions, Forchheim, Germany, and Siemens Medical Solutions USA, Hoffman Estates, IL, USA).

All FDG-PET scans were performed using standardized protocols including overnight fasting and preinjection blood glucose assessment. PET/CT was performed in the treatment position (prone position on a belly board).

The PET and CT datasets were transferred to a viewing station. The final dataset was transferred to a Varian Eclipse Radiation Treatment-Planning System.

Body weight-based standardized uptake value (SUV) was used as a semiquantitative tool to supplement visual interpretation. In this retrospective analysis, any suspected lesion with a maximum SUV > 2.5 which could not be explained by physiological activity was considered malignant.

There was no visually detected misregistration between CT and PET data.

**Target Volumes in Radiation Treatment Planning**

The target volumes were defined according ICRU 50, ICRU 62 reports.

All contours were delineated and analyzed by one radiation oncologist who was not involved in the patient’s original treatment planning. Target volumes were contoured first on CT alone (CT-GTV [gross tumor volume], CT-CTV [clinical target volume], CT-PTV [planning target volume]), without knowing of the PET information by the reader. Afterwards, PET/CT-GTV and PET/CT-PTV for hypothetical boost to macroscopic disease were delineated on the patient’s fused PET/CT dataset (Figure 1).

The CT-GTV included the entire circumference of the rectum at the level of the visible abnormality. Results of initial diagnostic procedures (rectoscopy, EUS, etc.) were used at the time of contouring on the planning CT.

CT-CTV was estimated according to recently published guidelines for delineation of rectal cancer [30, 38]. CT-PTV was defined as CT-CTV + 1 cm.

The PET/CT-GTV was defined including just PET information. A focus with the maximum SUV > 2.5 was contoured on the basis of the visual interpretation.

The PET/CT-PTV for hypothetical boost irradiation was defined as the PET/CT-GTV plus a 2-cm margin. 2-cm margin was based on RTOG recommendation [30].

Overlap volume (OV) of the CT- and PET-based GTVs was contoured as separate volume. Percentage of overlap (OV%) was calculated by dividing the OV by the CT-GTV [OV% = (OV cm³ / CT-GTV cm³) × 100%]. CT- and PET-based GTVs were additionally quantitatively compared by way of an index of conformality (CI). This index was calculated by dividing the OV by the whole volume of both GTVs. For the purpose of this analysis, OV% only are reported because there was a strong correlation of OV% and CI.

**Statistical Analysis**

Data were analyzed using SPSS software (version 14; SPSS Inc., Chicago, IL, USA). The quantitative values were expressed as median, mean ± SD (standard deviation). The