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## RESEARCH ARTICLE

# 18-F-FDG PET, PET/CT AND MDCT IN LOCALLY ADVANCED COLORECTAL CANCER

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**ABSTRACT**

The aim of our study was to assess contrast enhanced multi-detector CT (CE-MDCT), FDG-PET and FDG-PET/CT accuracy in loco-regional staging of colorectal cancer.

**Methods:** Eighteen (10 M, 8 F; aged 41-77 years) patients with histologically proven colorectal adenocarcinoma were enrolled. All patients underwent surgical resection within ten days of diagnostic assessment. CE-MDCT, FDG-PET and FDG-PET/CT were reviewed without knowledge of the results of histology. For each primary lesion a 3 point scale for characterization (1=benign, 2=indefinite, 3=malignant) and localization (1=uncertain, 2=probable, 3=certain) was used for FDG-PET and FDG-PET/CT. Sensitivity, specificity and accuracy were assessed for T staging for CE-MDCT and for N staging for CE-MDCT, FDG-PET and FDG-PET/CT.

**Results:** 19 adenocarcinomas were identified at surgery (one patients had two synchronous lesions). Both CE-MDCT and FDG-PET/CT correctly identified and localized all lesions, while FDG-P*Et al*one identified all lesions, but only 14 of them (74%) were correctly localized. T stage was correctly identified by CE-MDCT in 17/19 lesions (90%). CE-MDCT correctly staged N parameter in 12/19 lesions (63%). On the other hand, FDG-PET correctly staged N parameter in 11/19 (58%) lesions, while FDG-PET/CT correctly staged N parameter in 16/19 (84%, $p<0.05$ vs PET) lesions. Overall, FDG-PET/CT showed higher sensitivity than FDG-PET and higher specificity than CE-MDCT in evaluating lymph-node involvement ($p<0.05$).

**Conclusion:** These data suggest that fused FDG-PET/CT increases the accuracy of FDG-PET in localization of primary lesion and of both MDCT and FDG-PET in loco-regional N staging in patients with colon-rectal cancer.



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## INTRODUCTION

Colorectal cancer is the second most frequent malignancy in the Western countries, after breast cancer in women and lung cancer in men. Approximately 70-80% of patients are treated with curative intent and the overall survival at 5 years is less than 60% (Delbeke and Martin, 2004). The goals of oncologic imaging are lesion detection, lesion characterization, evaluation of the extent of neoplasm, staging and assessment of the therapeutic response. Staging includes lesion local infiltration as well as detection of nodal and distant metastases. Many therapeutic options are available for patients with colorectal cancer and an accurate preoperative staging is required for the choice of optimal therapy (Maier and Fuchsjager, 2003). Contrast enhanced (CE) computed tomography (CT) is widely used in the pre-operative staging of patients with colorectal cancer (Smith and Brown, 2008; Oxner *et al*., 2012). The introduction of helical CT and then of multidetector device has improved abdominal CT images, providing thin collimation, multiplanar reformatted images and improvement of spatial resolution. The performance of 18-fluoro-2-deoxyglucose positron emission tomography (FDG-PET) in patients with known or suspected primary colorectal cancer have been assessed by several studies in the last few years (Kantorova *et al*., 2003; Kunawudhi *et al*., 2016; Dias *et al*., 2007). Although sensitivity and specificity of FDG-PET imaging has been proven to be superior to that of CT in many clinical settings, the lack of anatomical informations of FDG remains a significant impairment in maximizing its clinical value (Delbeke and Martin, 2004). Because FDG is a tracer of glucose metabolism, its distribution is not limited to malignant tissue and knowledge of normal pattern and physiologic variation of FDG distribution, as well as clinical data of

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patients studied, is mandatory to optimize image interpretation (Culverwell *et al*., 2011). The introduction of integrated PET/CT systems provides CT and FDG-PET images in a single imaging setting, allowing optimal coregistration of images. Thus, fusion images allow accurate interpretation of both CT and FDG-PET studies. The addition of anatomic imaging may improve overall accuracy by correctly identifying increased FDG uptake (Kamel *et al*., 2004). The aim of the present study is to assess CE multi-detector CT (CE-MDCT), FDG-PET and FDG-PET/CT accuracy in locoregional staging of colorectal cancer.

## MATERIALS AND METHODS

### Patients

Eighteen (10 M, 8 F; aged 41-77 years) consecutive patients with a histologically proven diagnosis of colorectal adenocarcinoma were enrolled in the study. All patients underwent CE-MDCT and FDG-PET/CT in our department within one week. Informed consent was obtained from all the patients. All patients underwent surgical resection within ten days of imaging procedures.

### Pathologic TNM stage

Pathological findings for tumor invasion and nodal involvement served as the reference standard. T and N staging was based on the TNM classification (Boeker *et al*., 2016).

### CE-MDCT Protocol

All CE-MDCT examinations were performed using a four rows MDCT system (Aquilion, Toshiba). Scans were acquired using the following parameters: 4 x 3 mm collimation, pitch 5.5, 120 Kv, 300 mA, rotation time 0.5 s. The procedure was performed 70-80 seconds after the intravenous bolus (3 ml/sec) administration of 120 cc iodinated non ionic contrast agent, iopromide (Ultravist, 370 mg of iodine per millilitre; Schering, Berlin, Germany). Two abdominal radiologists, unaware of the histological findings, identified by consensus the tumors reporting size and localization. For the localization of each lesion, the large intestine was divided into eight anatomic segments: rectum, sigmoid colon, descending colon, splenic flexure, transverse colon, hepatic flexure, ascending colon and cecum. Colorectal wall invasion was analysed according to a modified T classification considering only three stages ($\leq$ T2, T3, T4), since CE-MDCT does not allow distinguishing between T1 and T2 lesions. Tumors confined to the bowel wall were defined as $\leq$ T2 lesions, while T3 lesions were defined as tumors with indistinct or speculated outer contour or with rounded or nodular advancing margins. Tumor infiltration into adjacent organs was considered stage T4 (Oxner *et al*., 2012). Regional lymph nodes were considered to be positive for metastases if a cluster of three nodes each < 1 cm in diameter or if a single node measuring at least 1 cm was present. This condition was classified as N1. Lymph nodes involvement was defined as N2 if more than three nodes regardless of their size were evident. The evaluation of non regional lymph nodes was not included in N parameter since their involvement is considered as distant metastases (M) (Boeker *et al*., 2016).

### PET/CT Protocol

All patients underwent PET/CT (Discovery LS, GE Medical Systems, Milwaukee, USA) 60 minutes after the intravenous administration of $^{18}$F-FDG (370/555 MBq). All studies were performed after fasting for 4 hours to lower insulin and blood sugar levels. In all patients blood sugar level was < 11 mmol/l. LS Discovery is an integrated system consisting in Advance NXi PET scanner and Light Speed Plus four rows MDCT system. MDCT parameters included 5 mm collimation (140 KV, 80 mA), 0.5 s/CT rotation, a pitch of 6. After completing MDCT, FDG-PET data were acquired with the patient in the same position on the table at five to seven bed positions (5 minutes for each bed position). Data obtained from the MDCT acquisition are used for low-noise correction of FDG-PET emission data and for fusion of attenuation-corrected PET images with the corresponding MDCT images. FDG-PET images were reconstructed with a 4.5 mm thickness. Reconstructed attenuation-corrected PET images, MDCT images, and fused images of matching pairs of PET and MDCT images are processed using a dedicated workstation (eNTEGRA, GE Medical System). Finally, FDG-PET, MDCT and fused FDG-PET/CT images of the same body range were reviewed directly from the computer screen of the workstation. Two nuclear medicine physician, unaware of both hystological and CE-MDCT findings, rewieved by consensus and in random order FDG-PET and FDG-PET/CT images. For each primary lesion identification, localization and characterization were assessed. Each identified lesion was characterized on the basis of visual evaluation of FDG uptake as: 1=benign (no or faint uptake), 2=indefinite (moderate uptake), 3=malignant (intense uptake). Localization of each lesion was classified using a 3 point scale: 1=uncertain, 2=probable, 3=certain. While on PET images focal perivisceral uptake was considered as nodal uptake, on PET/CT dimensions of the nodes were also taken in account. On PET images N0 was defined as no perivisceral uptake, N1 as not more than 3 foci of perivisceral uptake, and N2 if more than 3 were present. On the other hand, on PET/CT N1 was defined as FDG uptake in a cluster of three nodes each less 1 cm in diameter or in a single node measuring at least 1 cm, and N2 as $^{18}$F-FDG uptake in more than three nodes regardless of their size. In both analysis localization and characterization were assessed using the same score system used for primary lesions. The evaluation of non regional lymph nodes was not included in N parameter since their involvement is considered as distant metastases (M) (Boeker *et al*., 2016).

### Statistical Analysis

Sensitivity, specificity and accuracy were assessed by comparison with the histological results. Moreover, CE-MDCT sensitivity, specificity and accuracy were assessed for each T ($\leq$T2, T3, T4). Cochran-Q and McNemar's tests were used as appropriated and a p value $< 0.05$ was considered significant.

## RESULTS

### Histo-pathology

A total of 19 adenocarcinomas were identified at surgery with a patients showing two synchronous lesions. The lesions were localized in the rectum (n = 6), sigmoid-rectal junction (n = 1), sigmoid colon (n = 7), descending colon (n = 1), ascending colon (n = 1), cecum (n = 3). The histological examination classified 1 lesions (5%) as T1, 3 (16%) as T2, 10 (53%) as T3 and 5 (26%) as T4. Histological N stage showed lymph-nodal involvement in 9 cases (5 N1 and 4 N2).

**Table 1. T Stage by histology and CE-MDCT**

| | | Hystology | | |
|---|---|---|---|---|
| | | ≤ T2 | T3 | T4 |
| CE-MDCT | ≤ T2 | 3 | 1 | 0 |
| | T3 | 1 | 9 | 0 |
| | T4 | 0 | 0 | 5 |

**Table 2. N stage by histology and CE-MDCT**

| | | Histology | | |
|---|---|---|---|---|
| | | N0 | N1 | N2 |
| CE-MDCT | N0 | 4 | 1 | 0 |
| | N1 | 3 | 4 | 0 |
| | N2 | 3 | 0 | 4 |

**Table 3. Overall lymph-nodal staging: sensitivity, specificity, accuracy, positive and negative predictive values for fdg-pet alone, fdg-pet/ct and ce-mdct**

| | Sensitivity | Specificity | PPV | PNV | Accuracy |
|---|---|---|---|---|---|
| PET | 22% | 90% | 67% | 56% | 58% |
| PET/CT | 67% | 100% | 100% | 77% | 84% |
| CE-MDCT | 89% | 40% | 57% | 80% | 63% |

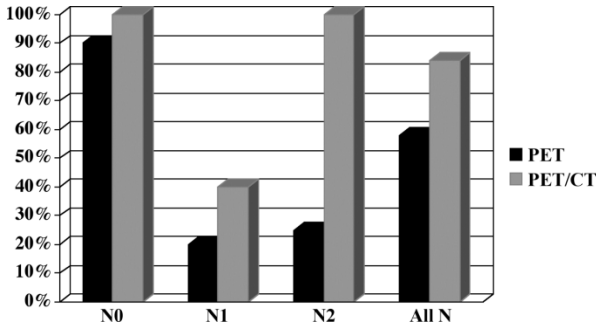


**Figure 1.**

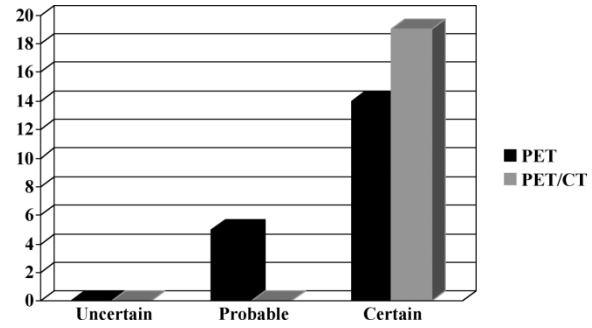


**Figure 2.**

### Tumor identification and localisation

Both CE-MDTC and FDG-PET/CT correctly identified and localized all the lesions. On the other hand, FDG-P*Et al*one identified all the 19 lesions, but only 14 of them (74%, $p<0.05$ vs both CE-MDTC and FDG-PET/CT) were correctly localized. Of the five lesions uncorrectly localized, 3 lesions of the cecum were erroneously attributed to the hepatic flexure, 1 of sigmoid colon to descending colon, 1 of sigmoid-rectal junction to sigmoid colon.

### Staging

T stage was correctly identified by CE-MDCT in 17 (90%) of 19 lesions: 3/4 ≤ T2, 9/10 T3 and 5/5 T4 (Table 1). In particular, CE-MDCT upstaged a T2 lesion as T3, while downstaged a T3 lesion as T2. CE-MDCT correctly staged N parameter in 12/19 (63%) lesions: 4/10 (40%) N0, 4/5 (80%) N1, 4/4 (100%) N2 (Table 2). Overall, N parameter was upstaged in 6 lesions and downstaged in 1 by MDCT. On the other hand, PET correctly staged N parameter in 11/19 (58%) lesions: 9/10 (90%) N0, 1/5 (20%) N1, 1/4 (25%) N2 (Figure 1). Overall, N parameter was downstaged in 7 lesions and upstaged in 1 by FDG-PET. FDG-PET/CT correctly staged N parameter in 16/19 (84%, $p < 0.05$ vs PET) lesions: 10/10 (100%) N0, 2/5 (40%) N1, 4/4 N2 (100%) (Figure 1). Overall, N parameter was downstaged in 3 lesions and upstaged in 0 by FDG-PET/CT. Table 3 reports sensitivity, specificity, accuracy, positive and negative predictive values for FDG-PEt *al*one, FDG-PET/CT and CE-MDCT when considering lymph-nodal involvement as present (N+) or absent (N0). FDG-PET showed only one false positive due to a para-uterine neoplastic focus considered as a lymph node. FDG-PET/CT showed a significantly ($p<0.05$) higher specificity than CE-MDCT, and a significantly ($p<0.05$) higher sensitivity than FDG-PEt alone Figure 2 shows side by side comparison of localisation and characterization of primary tumor by FDG-PEt alone and FDG-PET/CT: a 26% increase in localization certainty by PET/CT was observed.

## DISCUSSION

In the present study, all lesions were correctly localised by CE-MDCT and FDG-PET/CT, while FDG-P*Et al*one correctly localised 74% of lesions. T stage was correctly assessed by CE-MDCT in 90% of cases. Lesion localization was improved by FDG-PET/CT in comparison to FDG-PET in 26% of lesions. Moreover, N stage was accurate in 63% of cases using CE-MDCT, 58% using FDG-PET and in 84% using FDG-PET/CT. Accurate staging of colorectal cancer is relevant for subsequent therapeutic planning since different treatment options does exists (Clinical Outcomes of Surgical Therapy Study Group, 2004; Chawla *et al*., 2003). Both T stage and N stage have prognostic relevance, even in substratifying patients. The prognostic significance of tumor invasiveness has been reincorporated into the assessment of risk in patients with stage III disease. Greene *et al*. demonstred the prognosic significance of T–stage in node-positive patients (Greene *et al*., 2004). Within the N1 category T-stage was found to be highly prognostic, with patients with T1 or T2 disease faring significantly better than T3 or T4 tumors. Within the N2 population the prognosis was worse than for either subgroups of N1 patients, with T-stage no longer carryng prognostic significance. On the other hand, patients with stage II cancer as a group have a lower risk of harboring micrometastases than patients with stage III cancer. Patients with node positive colon cancer should receive postoperative chemotherapy (De Vita *et al*., 2015). However, no single test is capable of correctly staging both T and N parameter. FDG-PET may increase the ability to detect locoregional spread, lymph node involvement, as well as metastatic disease. However, few data on the utility of FDG-PET in the management of primary rectal cancer are so far reported. Accuracy of FDG-PET for detection of primary tumor has been reported to be 90% - 100%, but 25% - 75% for lymph node metastases (Kantorova *et al*., 2003; Rohren *et al*., 2002). Recently Kunawudhi *et al*. (2016) evaluated the accuracy of FDG-PET/CT for detection of malignant Colonic lesions. Abdel-Nabi *et al*. evaluated the usefulness of FDG-PET for staging patients with known or suspected primary colorectal carcinomas. In 48 patients, FDG-PET imaging

identified all primary carcinomas. They found that FDG-PET and CT were equally poorly sensitive for detecting local lymph node involvement, both with a sensitivity of 29%. However, FDG-PET was superior to CT for detecting hepatic metastases, with sensitivity and specificity of 88% and 100% respectively compared with 38% and 97% for CT (Abdel-Nabi *et al*., 1998). Mukai *et al*. (2000) and Kantorova *et al*. (2003) reported change in either treatment modality and the range of surgery using FDG-PET. In a prospective study assessing the potential impact of FDG-PET on treatment plan, 46 patients with primary rectal cancer were evaluated with conventional imaging (including endoscopy and CT) followed by FDG PET, and the treatment plan was prospectively recorded before and after the FDG PET scan. Preoperative stage changed in 39% of patients and management in 17% by FDG-PET (Heriot *et al*., 2004). Gearhart *et al*. evaluated whether FDG-PET/CT could provide additional information in patients undergoing standard evaluation for primary rectal cancer. They found that FDG-PET/CT frequently yields additional staging information in patients with low rectal cancer, with this improved accuracy allowing for more appropriate stage-specific therapy (Gearhart *et al*., 2006).

In the group of patients we studied, CE-MDCT accuracy for T stage (90%) is similar to that previously reported (Matsuoka *et al*., 2002). Both FDG-PET and FDG-PET/CT correctly identified all the lesions, with FDG-PET/CT showing a100% accuracy in cancer localisation, as already reported by others (Kantorova *et al*., 2003). However, no information on T stage was obviously provided even by FDG-PET/TC. Sensitivity for lymph nodal metastases by CE-MDCT in the present study was lower than that recently reported using a multidetector CT device (Filippone *et al*., 2004; Kulinna *et al*., 2004). Actually, these studies used: a) thinner collimation (1 mm); b) colonographic technique, which requires bowel preparation with a polyethylene glycol solution twenty-four hours prior to examination and colon air insufflation just before the CT scanning; c) multiplanar reformatted (MPR) images for the interpretation. Our less satisfactory results for lymph nodes evaluation may be explained, at least in part, by the fact thatin the present study a 3 mm collimation was used and that neither colonographic technique nor MPR images were performed. A very low sensitivity (22%) but a high specificity (90%) were obtained by FDG-PET in identifying the presence of lymph nodal involvement, these figures are in agreement with those previously reported (Kunawudhi *et al*., 2016). The unsatisfactory value of sensitivity is due to the low spatial resolution of PET and mainly to the lack of anatomical markers, making difficult the careful anatomical location of pathological uptake and a correct differentiation between physiological and pathological uptake. The introduction of hybrid PET/CT system allows to at least overcome the lack of anatomical landmarks (Delbeke and Martin, 2004). The development of PET/CT fusion images combines the benefits of the two imaging modalities and provides simultaneous metabolic and anatomic imaging information. A recent study of 62 patients with suspected rectal cancer recurrence compared the ability of FDG PET to FDG PET/CT to detect pelvic recurrence. The sensitivities of PET and PET/CT were 82% and 98%, respectively ($p < 0.01$), and the specificities of PET and PET/CT were 65% and 85%, respectively ($p < 0.01$) (Even-Sapir *et al*., 2004). Similar findings using fusion image technology have been reported by others, suggesting that detection of malignant disease and confirmation of lesion location may be improved by PET/CT fusion imaging (Cohade *et al*., 2003). In the present study FDG-PET/CT improved FDG-PET diagnostic interpretation. Actually, FDG-PET/CT correctly located all the primary lesions, with a diagnostic improvement in 26% of cases over FDG-P*Et al*one, and 8/9 lymph node metastases, with a diagnostic improvement in 55% of cases over FDG-P*Et al*one. When considering only the presence or absence of lymph nodal involvement FDG-PET/CT showed a better sensitivity than FDG-P*Et al*one and an higher accuracy than CE-MDCT. Both FDG-PET and FDG-PET/CT were highly predictive of N0 status. This would be a useful clinical tool in the setting of tumors being considered for local excision or for those having a complete pathologic response to neoadjuvant therapy. In both instances, if a test could predict N0 status with a high accuracy rate, then radical surgery could potentially be avoided.

In the present study, no intravenous contrast medium injection for CT images of PET/CT have been used. Since intravenous contrast medium helps to identify the lymph nodes by CT, improvement in diagnostic accuracy of FDG-PET/CT could be achieved in loco- regional staging of colorectal cancer by integrating contrast medium injection in the acquisition protocol. Thus, a more simple diagnostic procedure for the patient, a reduction in costs and in radiation dose could be obtained by including a "diagnostic quality CT scan for tumour survey" in the PET/CT examination (Berthelsen *et al*., 2005).

**Conclusion**

The data of the present study suggests that FDG-PET/CT increases the accuracy of FDG-PET in localization of primary colorectal cancer and of either CE-MDCT and PET FDG in loco-regional N staging in these patients.

## REFERENCES

Abdel-Nabi H, Doerr RJ, Lamonica DM, Cronin VR, *et al*. 1998. Staging of primary colorectal carcinomas with fluorine-18 fluorodeoxyglucose whole-body PET: Correlation with histopathologic and CT findings. *Radiology*, Mar;206(3):755-60.

Berthelsen AK, Holm S, Loft A, Klausen TL, *et al*. 2005. PET/CT with intravenous contrast can be used for PET attenuation correction in cancer patients. *Eur.J.Nucl Med and Mol.Imaging*., Oct;32(10):1167-75.

Boeker M, França F., Bronsert P, Schulz S. 2016. TNM-O: ontology support for staging of malignanttumours. *J Biomed Semantics*, Nov 14;7(1):64.

Chawla AK, Kachmic LA, Clark JW, Willett CG. 2003. Combined modality therapy for rectal and colon cancer. *SeminOncol*., Aug;30(4 Suppl 9):101-12.

Clinical Outcomes of Surgical Therapy Study Group. A comparison of laparoscopically assisted and open colectomy for colon cancer. N Engl J Med 2004; 350: 2050-9

Cohade C, Osman M, Leal J, Wahl RL. 2003. Direct comparison of (18) F-FDG PET and PET/CT in patients with colorectal carcinoma. *J Nucl Med*., Nov;44(11):1797-1803.

Culverwell AD, ScarsbrookAF, Chowdhury FU. 2011. False-positive uptake on 2-[18F]-fluoro-2-deoxy-D-glucose (FDG) positron-emission tomography/computed tomography (PET/CT) in oncological imaging. *ClinRadiol*., Apr;66(4):366-82

De Vita VT, Lawrence TS, Rosenberg SA, DePinho RA, *et al*. 2015. Hellman JrS, Rosenberg SA. CANCER Principles & Practice of Oncology.10th Edition, Wolters Kluwer.

Delbeke D, Martin WH. 2004. Pet and Pet/Tc for Evaluation of Colorectal Carcinoma. *Seminars in Nuclear Medicine*, Jul;34(3):209-223

Dias AR, Nahas SC, Camargo EE, Nahas CS. 2007. Recent evidences of the use of F-18-fluorodeoxyglucose positron emission tomography in the management of colorectal cancer. *J Surg Educ*., Mar-Apr;64(2):114-9

Even-Sapir E, Parag Y, Lerman H, Gutman M, *et al*. 2004. Detection of recurrence in patients with rectal cancer: PET/CT after abdominoperineal or anterior resection. *Radiology*, Sep;232(3):815-822.

Filippone A, Ambrosini R, Fuschi M, Marinelli T, *et al*. 2004. Preoperative T and N staging of Colorectal cancer: Accuracy of Contrast enhanced Multi-Detector Row CT Colonography-Initial Experience. *Radiology*, Apr; 231(1): 83-90.

Gearhart SL, Frassica D, Rosen R, Choti M, *et al*. 2006. Improved staging with pretreatment positron emission tomography/computed tomography in low rectal cancer. *AnnSurgOncol*., Mar;13(3):397-404.

Greene FL, Stewart AK, Norton HJ. 2004. A new TNM staging for node positive (stage III) colon cancer: an analysis of 50,042 patients. *J ClinOncol*., May 15;22(10): 1778-84

Heriot AG, Hicks RJ, Drummond EG, *et al*. 2004. Does positron emission tomography change management in primary rectal cancer? A prospective assessment. *Dis Colon Rectum*., 47: 451–458.

Kamel IR, Cohade C., Neyman E, Fishman EK, *et al*. 2004. Incremental value of CT in PET/CT of patients with colorectal carcinoma. *Abdominal Imaging*, Nov-Dec;29(6):663-8.

Kantorova I, Lipska L, Belohlavek O, Visokai V. *et al*. 2003. Routine (18)F-FDG PET preoperative staging of colorectal cancer: comparison with conventional staging and its impact on treatment decision making. *J Nucl Med*., Nov;44(11):1784–8.

Kulinna C, Eibel R, Matzek W, Bonel H, *et al*. 2004. Staging of Rectal Cancer: Diagnostic Potential of Multiplanar Reconstructions with MDCT. *AJR Am J Roentgenol*., Aug;183(2):421-7.

Kunawudhi A, Wong AK, Alkasab TK, Mahmood U. 2016. Accuracy of FDG-PET/CT for Detection of Incidental Pre-Malignant and Malignant Colonic Lesions - Correlation with Colonoscopic and Histopathologic Findings. *Asian Pac J Cancer Prev*., 17(8):4143-7.

Maier A, Fuchsjager M. 2003. Preoperative staging of rectal cancer. *Eur J Rdiol*., Aug; 47(2): 89-97

Matsuoka H, Nakamura A, Masaki T, Sugiyama M, *et al*. 2002. Preoperative staging by multidetector-row computed tomography in patients with rectal carcinoma. *The American Journal of Surgery*, Aug;184(2):131-5.

Mukai *et al*. Mukai M, Sadahiro S, Yasuda S, *et al*. 2000. Preoperative evaluation by whole-body 18F-fluorodeoxyglucose positron emission tomography in patients with primary colorectal cancer. *Oncol Rep*., Jan-Feb;7(1):85-7.

Oxner CR, Nelson RA, Lee W, Duldulao MP, *et al*. 2012. Accuracy of computed tomography in staging colon cancer patients. *J ClinOncol*., 30(4_suppl):614

Rohren EM, Paulson EK, Hagge R, Wong TZ, *et al*. 2002. The role of F-18 FDG positron emission tomography in preoperative assessment of the liver in patients being considered for curative resection of hepatic metastases from colorectal cancer. *ClinNucl Med*., Aug;27(8):550–5.

Smith N. and Brown G. 2008. Preoperative staging of rectal cancer. *ActaOncol*., 47(1): 20-31

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