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Clinical value of ^{18}F-FDG PET/CT in postoperative monitoring for patients with colorectal carcinoma

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ABSTRACT

Objective: To evaluate the clinical value of ^{18}F-FDG PET/CT in postoperative monitoring for patients with colorectal carcinoma. *Methods*: 66 postoperative patients with colorectal carcinoma underwent whole-body FDG PET/CT. The final histopathological and formal clinical follow-up findings were used as gold standard to determine the sensitivity and specificity of FDG PET/CT and enhanced CT of the same periods. *Results*: The sensitivity and specificity of FDG PET/CT in detecting recurrence are 96.30%, 94.87% (while enhanced CT are 70.37% and 87.18% respectively). The sensitivity and specificity in detecting metastasis are 95.35%, 82.61% (enhanced CT are 61.90%, 75.00%). SUVmax was significantly higher in malignant lesions [range 4.16–22.00, mean ± standard deviation ($x \pm s$) 8.06 ± 4.30] than in benign ones (range1.18–6.25, $x \pm s$ 2.82 ± 1.02). *Conclusion*: At present, whole-body ^{18}F-FDG PET/CT is an advanced diagnostic imaging technique in detecting loco-regional recurrence and metastasis in postoperative patients with colorectal carcinoma for its higher sensitivity and specificity.

1. Introduction

Colorectal carcinoma (CRC) is the third most common malignant lesions worldwide and associated with a high mortality rate. Radical resection is the primary therapy for colorectal carcinoma, but the local recurrence and (or) metastasis rate in two years after operation are up to 30–40% [1–4]. Early detection and accurate staging is very helpful for designing the subsequent clinical therapeutic scheme for example secondary operation, radiotherapy or (and) chemotherapy. At present, serum carcinoembryonic antigen (CEA) and enhanced CT are conventional means. In general, serial serum CEA levels are used for recurrence monitoring, but when a high serum level of CEA is encountered, imaging will be necessary to localize the site of possible recurrence or metastasis. Due to changes of anatomical structures and fibrous tissue hyperplasia in the operative region, enhanced CT is usually incapable of differentiating post surgical changes from recurrence and also it commonly misses extrahepatic abdominal metastases and fails to detect hepatic metastases in 7% patients as well [5]. Functional imaging with FDG PET can be successfully used to identify the metabolic characteristics of the lesions, which are equivocal or even not seen by CT. The purpose of this study was to compare the clinical value of enhanced CT and ^{18}F-FDG PET in detecting loco-regional recurrence and metastasis in postoperative patients with colorectal carcinoma.

2. Materials and methods

2.1. Patients

From July 2005 to June 2009, 66 postoperative patients with colorectal carcinoma were recruited in our study. The inclusion criteria were as follows: (1) 18–65 years of age (2) had diagnosed colorectal cancer and were performed radical resection (3) completed special therapy including radical resection, radiotherapy or (and) chemotherapy at least 2 months (4) clinicopathological stages I–III, KPS score ≥ 70 (5) without another primary malignant condition (6) complete clinical and follow-up data. Serum tumor markers of CEA and enhanced CT were performed for all patients within 1 week before PET/CT scanning with no special treatment for example high radiation doses delivered to patients et al. during this period. Formal clinical follow-up including histologic confirmative exam or treatment, regular imaging (US, MRI and CT) ranged from 6 months to 32 months, with an average of 17 months.

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2.2. CEA examination

Serum CEA were determined by electrochemiluminescence immunoassay with normal reference range 0–3.4 ng/ml. It was believed positive when it exceeded 3.4 ng/ml.

2.3. CT technique

All the patients included in the study underwent multi-detector CT scanning (sixteen-detector row; Sensation 16, Siemens, Erlangen, Germany) according to an established protocol. Each patient fasted for six hours before undergoing whole-body enhanced CT from the level of the vertex to the ischial tuberosities in a prone position. Intravenous administration of a total volume of 150 ml (maximum) or 2 ml/kg of iodinated contrast material (Iopromide [Ultravist], Bayer Schering) containing 300 mg of iodine/ml via power injection at a rate of 2.5 ml/s was performed, and the scan of neck–thorax, upper–middle abdomen and lower abdomen–pelvis was started at 45 s, 75 s and 90 s, respectively, after injection, at 140 kV and 230 mA with 0.75–7.0 mm section collimation, a pitch of 1.0–1.5 and 3.0–7.0 mm of reconstruction thickness. The transverse images were reconstructed with a soft-tissue algorithm. No oral contrast agent was administered.

2.4. PET/CT scanning

^{18}F-FDG PET/CT scans were obtained with an integrated PET–CT system (GE Discovery LS, GE Healthcare). All patients fasted for at least 6 h before the injection of 5.55–7.40 MBq/Kg of 18F-fludeoxyglucose (^{18}F-FDG). The blood glucose levels were checked in all patients before FDG injection and no patients showed a blood glucose level of more than 160 mg/dl. Intravenous injection was performed through a previously inserted infusion line into the elbow vein. For 60 min after injection, patients were reclined in a quiet room with minimal muscular activity. Then patients were immobilized using customed immobilization cradle in supine position with arms overhead. The PET/CT system was used for 4-slice helical CT acquisition, followed by a full-ring dedicated PET scan of the same axial range. The CT component was operated with an X-ray tube voltage peak of 120 keV, 90 mA, a 6:1 pitch, a slice thickness of 5 mm, and a rotational speed of 0.8 s/rotation. PET scans were obtained from head to thigh for 4 min per field of view, each covering 14.5 cm, at anaxial sampling thickness of 4.25 mm/slice. Both the PET scans and the CT scans were obtained during normal tidal breathing. PET images were reconstructed with CT-derived attenuation correction using ordered-subset expectation maximization software. The attenuation-corrected PET images, CT images, and fused PET/CT images were available for review in axial, coronal, sagittal planes and a cine display of maximum intensity projections of the PET data, using the manufacturer's review station (Xeleris; GE Healthcare). The delayed scanning were performed 3 h after FDG injection when it was difficult to make differential diagnosis of benign and malignancy lesions.

2.5. Analysis on imaging and data

Contrast-enhanced CT images were retrospectively evaluated in consensus by two experienced radiologists (reader A and reader B with 12 and 25 years of experience in CT, respectively) who had knowledge of neither the other imaging results nor the clinical data. CT images were viewed in coronal, axial and sagittal sections and inspected and appropriate winding was applied. Peritoneal implantation was diagnosed when nodular, plaque-like or infiltrative soft tissue lesions with abnormal enhancement were seen in the peritoneal fat or on the peritoneal surface. Lymph nodes (LNs) with a short-axis diameter greater than 1 cm were defined as malignant. Furthermore, the presence of a central unenhancing area suggesting central necrosis was considered a sign of malignancy, and the presence of peripheral low attenuation suggesting a fatty hilum within an LN was considered a benign sign, regardless of node size [6–8].

On Xeleris station, CT, PET and fused PET/CT images were opened simultaneously and reviewed by a combined team of nuclear medicine physicians and radiologists (with 3–6 years of experience in PET/CT), comparing and analyzing PET images and CT images side-by-side using visual observation and semi-quantity analysis: it was considered positive when the maximum standard uptake value (SUVmax) of region of interesting (ROI) in early and delayed phase exceeded 2.5, and also ΔSUVmax/SUVmax $> 20\%$ (ΔSUVmax = delayed phase SUVmax-early phase SUVmax). In most cases, intestinal peristalsis or intestinal benign diseases such as inflammatory lesions also manifested as higher radioactivity uptake and SUVmax may exceed 5, but the line feed of the latter was consistent with digestive tract, without obvious mass or space occupying lesions, combined with CT findings for example morphological characteristics, density, distribution and delayed-phase PET findings for example changes of degree and location of radioactivity uptake, which was helpful for us to differentiate. Confirmed diagnosis of recurrence and metastasis was on the basis of postoperative pathological examination of secondary operation, colonoscopy/rectoscopy, various imaging examinations and formal clinical follow-up.

2.6. Statistical analysis

Sensitivity, specificity and accuracy were calculated using standard statistical formula. Formula for calculating diagnostic efficacy of PET/CT in detecting recurrence and metastasis was as follows: sensitivity = true positive results/(true positive results + false negative results), specificity = ture negative results/(ture negative results + false positive results). Differences between the two imaging modalities were tested by using the McNemar test with Bonferroni adjustment; p values of less than 0.05 were considered to indicate statistical significance. Differences of SUVmax between malignant lesions and benign ones were made statistics analysis processing using two-sample *t*-test for independent samples.

Contrast-enhanced CT and FDG PET/CT.

	Results (*n*: cases)		
	Contrast-enhanced CT	FDG PET/CT	Pathology and formal clinical follow-up
Nothing abnormal	34	21	24
Recurrence	24	28	27
LN metastasis	16	23	22
Supraclavicular LN	1	2	2
Chest LN	2	4	3
Abdominal LN	5	8	9
Pelvic LN	8	9	8
Peritoneal dissemination	5	7	8