Improvement in Preoperative Staging of Gastric Adenocarcinoma with Positron Emission Tomography

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BACKGROUND. Positron emission tomography (PET) with 18- fluorodeoxyglucose (FDG) has been used to both detect and stage a variety of malignancies. The current study examined the value of PET for preoperative staging of gastric adenocarcinoma.

METHODS. Sixty-eight patients (49 males and 19 females) with gastric adenocarcinoma, who were referred for preoperative FDG-PET scans, were enrolled in this study. The patients underwent spiral-computed tomography (CT) within 1 week of referral. The final diagnosis in all patients was made by histologic and surgical findings. For quantitative PET analysis, the regional tumor FDG uptake was measured by the standardized uptake value (SUV).

RESULTS. For the primary tumor of a gastric adenocarcinoma, PET demonstrated an increased uptake in 64 of 68 patients (sensitivity, 94%), with a mean SUV of 7.0 (range, 0.9–27.7). A comparison of FDG uptake and clinicopathologic features showed significant association between FDG uptake and macroscopic type, tumor size, lymph node metastasis, histologic type, and TNM stage. The PET scan had a similar accuracy with that of CT for diagnosing local and distant lymph node metastases as well as peritoneal status. In assessing local lymph node status, however, PET had a higher specificity than CT (92% vs. 62%, $P = 0.000$). Moreover, PET had additional diagnostic value in 10 (15%) of 68 patients by upstaging 4 (6%) and downstaging 6 (9%) patients. PET combined with CT was more accurate for preoperative staging than either modality alone (66% vs. 51%, 66% vs. 47%, respectively; $P = 0.002$).

CONCLUSIONS. FDG-PET improves the preoperative TNM staging of gastric adenocarcinoma. Based on its superior specificity, FDG-PET can facilitate the selection of patients for a curative resection by confirming a nodal status identified by CT. ***Cancer*** **2005;103:2383–90.** © *2005 American Cancer Society.*

KEYWORDS: gastric adenocarcinoma, positron emission tomography, computed tomography, TNM staging.

Carcinoma of the stomach has a poor prognosis because many patients have advanced disease at the time of diagnosis.[1–3] Therefore, pretreatment assessment and staging of disease is essential for managing gastric carcinoma.[4] The tumor stage provides the basis for selecting the most appropriate therapeutic strategy.

Preoperative staging currently relies on a standard noninvasive imaging modality of spiral-computed tomography (CT) of the abdomen and pelvis. However, CT is an anatomy-based diagnostic technique with certain drawbacks, including limited sensitivity from false-negative findings due to nonenlarged invaded lymph nodes and limited specificity from false-positive findings due to enlarged inflammatory lymph nodes. Therefore, a better preoperative evaluation

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strategy would greatly aid the preparation of treatment plans for patients with gastric carcinoma.

Positron emission tomography (PET) using the radiolabeled glucose analogue, ^{18}F-fluorodeoxyglucose (FDG), as a tracer is a well established imaging technique that offers new perspectives in staging malignant diseases. FDG-PET scanning enables observation of altered glucose metabolism in neoplastic cells.[5] These images are complementary to traditional morphologic images, such as those produced by CT, and may be more sensitive because functional changes often precede anatomic changes. Several studies have confirmed the added value of PET for detecting occult metastases in patients with esophageal as well as head and neck carcinomas.[6,7] Flamen et al. reported that PET improved staging in an esophageal carcinoma with a specificity of lymph node staging.[8]

The TNM system is generally acknowledged as the principal method for assessing extent of disease and for determining the prognosis of gastric carcinoma patients. The aim of the current study was to prospectively assess the value of FDG-PET scanning for preoperative staging of gastric adenocarcinoma. In particular, this study aimed to assess and compare the value of CT and FDG-PET scanning in diagnosing nodal involvement.

MATERIALS AND METHODS

Patients

Sixty-eight patients with an esophagogastroduodenoscopy biopsy-proven gastric adenocarcinoma, who were referred between August 2000 and June 2003 to the Department of Surgery of Yonsei University College of Medicine for an evaluation of tumor resectability, were enrolled in this study. The exclusion criteria were previous gastric cancer treatment, diabetes mellitus, and inoperability for medical reasons. All patients underwent routine staging procedures, including medical history and physical examination, laboratory tests, upper gastrointestinal barium study, and spiral CT of the abdomen and pelvis. In addition, FDG-PET scanning was performed within the same week.

Spiral CT of the Abdomen and Pelvis

CT scans with contiguous 7 mm slice thickness were performed on all patients by a Somatom Plus-S (Siemens, Munich, Germany), Tomoscan 310 (Philips, Amsterdam, The Netherlands), or a LightSpeed Plus (GE Healthcare, Waukesha, WI). The enhanced CT scans were obtained after bolus intravenous injection of a concentration of 60% wt/vol of iodine contrast medium at a 2–4 mL/sec velocity with a volume of 2 mL/kg up to a maximum volume of 150 mL. Scans were taken during a single breath hold.

Extent of the primary tumor, thickness of stomach wall, tumor invasion of adjacent structures, and presence of a lesion suggesting metastasis to distant sites were recorded. Lymph nodes (LN) measuring 10 mm or more at their maximum cross-sectional diameter were considered metastatic. An abdominal radiologist, who was blinded to the FDG-PET findings, interpreted all CT examinations prospectively.

FDG-PET

PET scans were performed using a PET scanner (GE Advance, Milwaukee. WI) with an axial field of view of 55 cm and a spatial resolution of 5 mm in the center of the field of view. All patients fasted for at least 4 hours before the scan, and blood samples were taken immediately before analyzing glucose level to confirm patient normoglycemia. Transmission scans were obtained in six bed positions, ranging from maxilla down to proximal thighs. Thereafter, 370–555 Mbq of FDG was injected into an antecubital vein, and the PET imaging was begun after a 60-minute uptake period. The emission scan was obtained in 6 bed positions (5 min in each bed position), using the same sequence and range as transmission scans. All images were corrected for delay and photon attenuation and were reconstructed in a 128×128 matrix using an iterative reconstruction algorithm with 32 iterations. The FDG activity within each tumor was corrected for its physical decay and was normalized by the administered dose as well as the patients' weight to produce a Standardized Uptake Value (SUV), using a 3-point scale, ranging from 1 (normal), 2 (equivocal), to 3 (abnormal). For this analysis, scores of 2 and 3 were considered positive. SUVs of abnormal sites were also recorded as follows: SUV = (activity per cc) ÷ (injected activity per grams of body weight). In determining the SUV, a region of interest was drawn around the lesion, and the maximum activity was used to minimize the inter- and intra-observer variability. Image processing and reconstruction were performed using a high-resolution display monitor (SUN workstation; Sun Microsystems, Mountain View, CA). Two experienced nuclear medicine physicians evaluated all PET images, and there was 100% agreement between them. The preliminary PET interpretation was performed without prior knowledge of patient history including CT findings. PET images were compared using CT images for the final interpretation, and patient management was based on a combined interpretation.

Patient Management

Discordant PET data affecting the patient staging and/or management were considered only if they were confirmed by histology or by dedicated radiographic techniques. All staging was assigned using the guidelines from the 5th American Joint Committee on Cancer (AJCC) TNM staging guidelines.[4] The treatment represented a consensus individualized for each patient.

Surgery

Standardized surgical procedures were performed as follows: 1) a total or distal subtotal gastrectomy depending on the location and the macroscopic type of the gastric cancer; 2) a D2 or D3 lymphadenectomy. A lymph node dissection was classified according to rules set down by the Japanese Research Society for Gastric Cancer (JRSGC).[9] The definitions of a D2 and D3 lymphadenectomy are as follows: Regional lymph nodes of the stomach were classified into four compartments according to rules from the JRSGC. Compartment I consisted of the perigastric lymph nodes. Compartment II consisted of the lymph nodes along the left gastric artery, along the common hepatic artery, around the celiac axis, and along the splenic artery. Compartment III consisted of lymph nodes in the hepatoduodenal ligament, at the posterior aspect of the head of the pancreas, and at the root of the mesentery. Lymph nodes along the splenic artery were classified as being in Compartment III when the cancer was located in the lower third of the stomach. Compartment IV consisted of lymph nodes along the middle colic vessels and the paraaortic lymph nodes. The anatomic level of a D2 lymphadenectomy included a complete dissection of Compartments I and II, whereas a D3 lymphadenectomy included those of Compartments I, II, and III. In this study, Compartment I or II was classified in the local lymph node group, whereas Compartment III or IV was classified in the distant lymph node group. 3) A gastrectomy with an additional organ resection was performed to either facilitate a more extensive lymph node dissection or to gain a complete tumor resection. 4) A gastrectomy was not performed on those who had a distant metastasis including a multiple peritoneal dissemination, multiple liver metastatic lesions and local far advanced disease, and those patients usually undergoing a bypass without a resection or an exploratory (nontherapeutic) laparotomy with a node biopsy.

The level of the dissected lymph nodes from excised specimens were verified by surgeons, and all retrieved lymph nodes were examined for a metastasis by optical microscopy after being stained with hematoxylin and eosin. The histologic classification of a gastric cancer was determined according to the JRSGC classification.

Data Analysis

Imaging results were compared using the gold standard provided by a histologic examination of routine hematoxylin-eosin–stained sections of the tissue obtained from a gastrectomy in 61 patients, an exploratory (nontherapeutic) laparotomy with a perigastric LN biopsy in 4 patients, and a laparotomy bypass with a perigastric LN biopsy in 3 patients.

The gold standard for T stage was exclusively defined by histology. Therefore, it was only available in the subgroup of patients in whom either a curative or palliative gastrectomy had been performed. To assess involvement of lymph nodes, the gold standard was exclusively defined by a histologic examination of tissue obtained in patients in whom either a D2 or D3 lymphadenectomy or a perigastric LN biopsy had been performed.

For analysis of the accuracy of the combined use of FDG-PET and CT, the positive results of both techniques were cumulated. Therefore, a positive result with one technique overruled a negative result with the other.

Statistics

The statistical software package for social science (SPSS) version 10.0 for Windows (SPSS. Inc, Chicago, IL) was used for all statistical analyses. The relation between FDG uptake and other parameters was determined using the one-way ANOVA method. A simple regression analysis was used to determine the relation between FDG uptake and tumor size. The sensitivity, specificity, and accuracy of CT and FDG-PET imaging modalities were estimated using the standard definition.[10] A chi-square test, a McNemar test, and a Fisher exact test were used to examine significance of correlated proportions between the FDG-PET and CT findings. A P value of < 0.05 was considered significant.

RESULTS

Patient Characteristics

Of the 68 patients in this study, there were 19 women and 49 men with a mean age of 54.8 years (range 28–81yrs). Eight patients had early gastric cancer (EGC), and 60 had advanced gastric cancer (AGC) with a mean tumor size of 6.8 cm. Tumor penetration of the serosa (T3) was the most common type of invasion (50 of 68 patients, 73.5%). There were 47 patients with local LN metastases, and 8 patients with distant LN metastases. A histologic diagnosis of a differentiated

adenocarcinoma was made in 13 patients, and the other 55 were diagnosed with an undifferentiated adenocarcinoma. Two patients had hematogenic metastases (1 liver, 1 spleen). Ten patients had documented peritoneal dissemination. According to the 5th AJCC TNM classification, there were 10 patients with Stage I disease, 4 patients with Stage II disease, 29 patients with Stage III disease, and 25 patients with Stage IV disease. Fifty-eight patients underwent a curative gastrectomy with a D2 or D3 lymphadenectomy, and 3 patients underwent a palliative gastrectomy with a D2 lymphadenectomy. Four patients underwent exploratory (nontherapeutic) laparotomy with perigastric lymph node biopsy, and another three patients received bypass surgery with a perigastric lymph node biopsy (Table 1).

TABLE 1
Clinicopathologic Features of Gastric Adenocarcinomas

Parameter	No. (n = 68)	%
Age (mean, 54.8 yrs)		
Gender		
Male	49	72
Female	19	28
Macroscopic type		
EGC	8	12
AGC	60	88
Tumor size (median, 6.8 cm)		
Depth of invasion		
T1	8	12
T2	2	3
T3	50	74
T4	1	1
Unknown[a]	7	10
LN metastasis[b]		
N0	13	19
N1	19	28
N2	14	21
N3	15	22
Unknown[a]	7	10
Extent LN metastasis		
N0	13	19
L-LN	47	69
D-LN[a]	8	12
Histologic type		
Tubular adenocarcinoma	56	82
Mucinous and SRC	12	18
Stage		
I	10	15
II	4	6
III	29	42
IV	25	37
Hematogenic metastasis	2	3
Peritoneal dissemination	10	15
Curability		
Curative	58	85
Palliative	10	15

EGC: early gastric cancer, AGC: advanced gastric cancer, L-LN: local lymph node, D-LN: distant lymph node, SRC: signet ring cell adenocarcinoma.
[a] Data was unavailable in 7 patients because they did not undergo gastrectomy and lymphadenectomy.
[b] According to the 5th AJCC classification.

Primary Tumor Assessment

FDG-PET demonstrated increased activity in the primary gastric adenocarcinoma in 64 of the 68 patients (sensitivity, 94%), with a mean SUV of 7.0 (range, 0.9–27.7). Figure 1 shows a typical FDG-PET scan of a patient with gastric adenocarcinoma. The scan shows intense uptake in the stomach and another area of intense uptake (lymph node metastasis) in the perigastric lesion. False-negative (FN) PET images were obtained from 4 patients, 3 were pT1 lesions, (all of which were confined to the mucosa with a diameter < 3 cm), and 1 was a pT3 lesion (the diameter was 4 cm, gross type, Borrmann 3, signet ring cell adenocarcinoma). When assessed by quantitative analysis, the mean SUV was higher in AGC (7.5) than in EGC (2.1) ($P = 0.016$) (Table 2). There was a significant difference in PET sensitivity in detecting a primary AGC and an EGC (98% vs. 63%, $P = 0.004$). The mean SUV was higher in the tubular adenocarcinoma group than in the mucinous and signet ring cell adenocarcinoma (SRC) group (7.7 vs. 4.2, $P = 0.043$) (Table 2). The sensitivity of the CT scan for diagnosing a primary tumor was 93% (63 of 68 patients). The CT scan failed to detect a primary tumor in three patients (two pT1 mucosa lesions; one pT3 poorly differentiated adenocarcinoma). The CT scan misdiagnosed two early gastric cancer patients by upstaging them to advanced gastric cancer. The sensitivity of PET and CT imaging in diagnosing a primary tumor was similar (94% vs. 93% $P = 0.164$). We also found significant correlation between tumor size and SUV (Fig. 2).

Diagnosis of LN Metastasis

Sixty-one (90%) of the 68 patients underwent a D2 or D3 lymphadenectomy in conjunction with a primary gastrectomy (58 curative resection, 3 palliative resection). The histologic diagnoses were as follows: No LN involvement in 13 (19%) patients, local LN involvement in 47 (69%) patients, and distant LN involvement in 8 patients. Seven (12%) patients were unavailable for a distant LN histologic diagnosis for those who did not undergo a lymphadenectomy (Table 1). Patients with lymph node metastasis (N1–3) had a higher SUV than that of the N0 group ($P = 0.034$) (Table 2).

Table 3 gives an overview of calculated sensitivities, specificities, and accuracy of the imaging modalities for diagnosing LN involvement in this study group. In detecting a local LN, the sensitivity of PET was lower than that of CT (56% vs. 78% $P = 0.002$), but

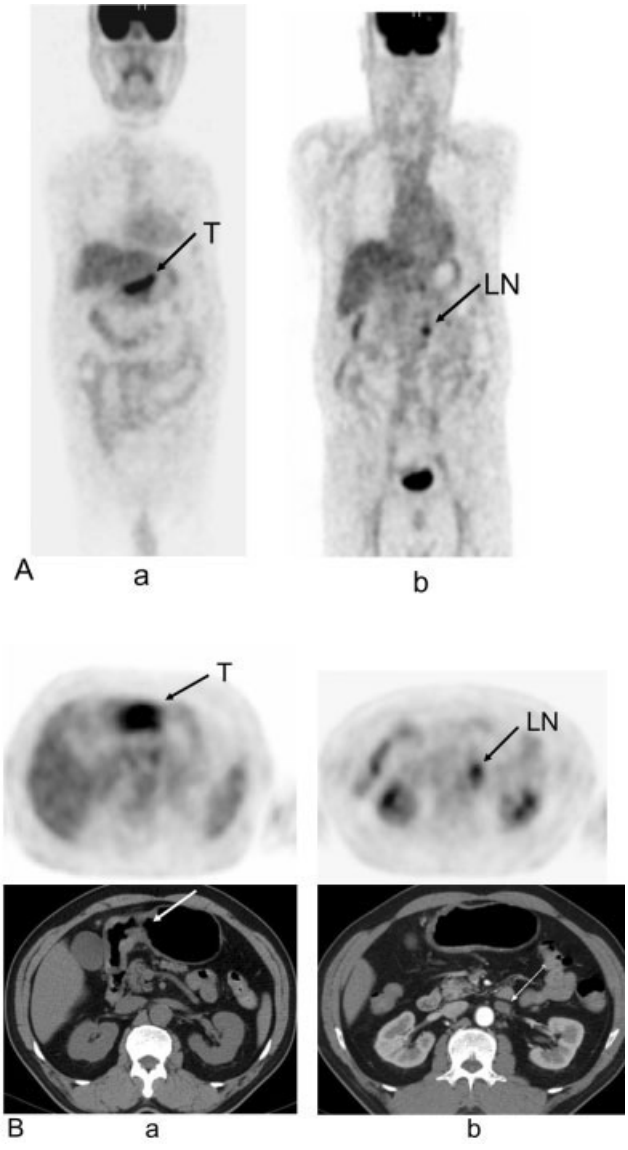

FIGURE 1. Primary adenocarcinoma of stomach with local lymph node involvement. (A) Coronal PET scan demonstrates a primary tumor (T arrow) and a local lymph node (LN arrow) with increased FDG uptake. (B) Axial PET scan and CT scan demonstrate a primary tumor and a local lymph node (arrows).

the specificity was higher (92% vs. 62% $P = 0.000$). However, overall accuracy of PET in detecting both local and distant LN metastasis was not significantly different from that of CT.

Detection of Hematogenic Metastasis and Peritoneal Dissemination

Two (3%, 2 of 68)patients had a hematogenic metastasis that was confirmed by histology after surgery (1 liver, 1 spleen). PET showed a false negative in the liver metastasis lesion and a true positive in the spleen metastasis lesion. CT showed false-negative results in spleen metastasis lesions, and a true-positives in liver lesions. The false-positive findings from PET and CT were all found in liver lesions (3 patients vs. 2 patients, respectively), of which there was no evidence that these lesions were found during surgery and no further manifestation was noted during followup.

In the situation of a peritoneal dissemination, a

TABLE 2
Relation between FDG uptake and Clinicopathologic Features of Gastric Adenocarcinoma

Parameter	No. ($n = 68$)	SUV (mean)	F	P value[a]
Macroscopic type				
EGC	8	2.1	6.142	0.016
AGC	60		7.5	
Histologic type				
Tubular	56	7.7	4.290	0.043
Mucinous/SRC	12	4.2		
LN metastasis[b]				
N0	13	3.6	4.780	0.034
N1	19	7.5		
N2	14	7.4		
N3	15	8.7		
Peritoneal dissemination				
Positive	10	6.8	0.021	0.887
Negative	58	7.0		
Stage				
I or II	14	3.7	6.504	0.013
II or IV	54	5.4		

EGC: early gastric cancer, AGC: advanced gastric cancer, LN: lymph node, SRC: signet ring cell adenocarcinoma.

[a] The results were using the analysis of one-way ANOVA method; $P < 0.05$ was considered significant.

[b] Data were unavailable for 7 patients because they did not undergo gastrectomy and lymphadenectomy. LN metastasis and stage classification were according to the 5th AJCC classification.

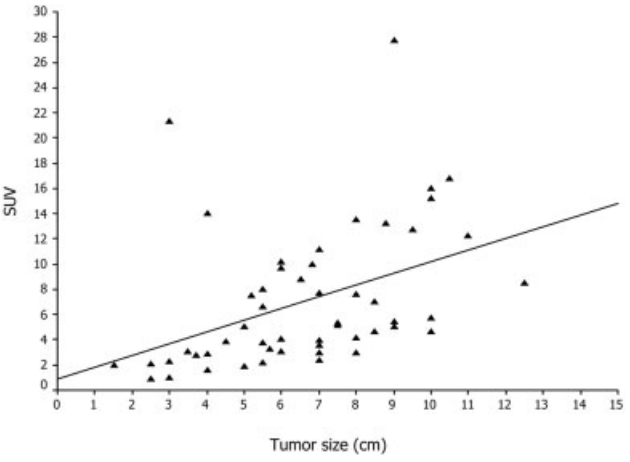

FIGURE 2. Relation between FDG uptake (standardized uptake value, SUV) and longitudinal diameter of primary tumor. $Y = 1.892 + 0.791X$; $R^2 = 0.176$; $F = 10.910$; $P = 0.002$.

TABLE 3
Preoperative Assessment of Lymph Node and Peritoneal Metastases

	PET (%)	CT (%)	*P* value[a]
Sensitivity			
L-LN	31 of 55 (56)	43 of 55 (78)	0.002
D-LN	7 of 8 (88)	6 of 8 (75)	1.000
Peritoneum	3 of 10 (30)	8 of 10 (80)	0.063
Specificity			
L-LN	12 of 13 (92)	8 of 13 (62)	0.000
D-LN	51 of 53 (96)	48 of 53 (91)	0.219
Peritoneum	57 of 58 (98)	53 of 58 (91)	0.125
Accuracy			
L-LN	43 of 68 (63)	51 of 68 (75)	0.115
D-LN[b]	58 of 61 (95)	54 of 61 (89)	0.180
Peritoneum	60 of 68 (88)	61 of 68 (89)	1.000

L-LN: local lymph node, D-LN: distant lymph node.
[a] Results were compared by MacNemar test for correlated proportions; $P < 0.05$ was considered significant.
[b] Data were unavailable for 7 patients because they did not undergo gastrectomy and lymphadenectomy.

TABLE 4
Overall Accuracy of Preoperative Staging in Patients with Gastric Adenocarcinoma

	Correct		False		
	n	%	n	%	*P* value[a]
PET	32	47	36	53	0.002
CT	36	53	32	47	
PET + CT[b]	46	68	22	32	

[a] Results were compared by Chi-square test; $P < 0.05$ was considered significant.
[b] Correct results of both techniques were cumulated. Therefore, a correct result with one technique overruled a false result with the other.

total of 10 (15%, 10 of 68)patients were diagnosed with peritoneal dissemination based on a surgical and histologic confirmation. The mean SUV shows no significant difference in peritoneal dissemination (Table 2). Both PET and CT had a high accuracy for diagnosing a peritoneal dissemination (88% vs. 89% P = not significant) (Table 3). CT showed a higher sensitivity compared with PET (80% vs. 30%), but it did not reach statistical significance ($P = 0.063$).

Improvement in Preoperative Staging with FDG-PET

For TNM staging according to FDG uptake, the mean SUV was higher in Stages III and IV than in Stages I and II (5.4 vs. 3.7, $P = 0.013$) (Table 2).

Overall, the accuracy of preoperative staging using PET, CT, and PET combined with CT was 47% (32 of 68 patients), 53% (36 of 68 patients), and 68% (46 of 68patients), respectively, ($P = 0.002$) (Table 4). PET combined with CT had significantly higher accuracy in preoperative staging than PET or CT alone. PET tended to understage (44%, 30 of 68 patients), whereas CT tended to overstage (24%, 16 of 68 patients). For example, PET upstaged 4 patients (6%, 4 of 68 patients) from the CT staging (1 spleen metastasis lesion, 1 distant LN, 1 local LN, and 1 primary lesion), and downstaged 6 (9%, 6 of 68) patients from CT staging (2 peritoneal dissemination, 3 distant LN, and 1 liver metastasis). The additional value of PET preoperative staging was found to be 15% (10 of 68 patients).

DISCUSSION

Accurate pretreatment staging in gastric cancer is extremely important for providing information on potential curability as well as for planning an optimal therapeutic strategy.[5] The mainstay of clinical staging is still based on the CT scan, but the accuracy of CT alone for making an optimal preoperative diagnosis remains to be confirmed.[11–14] CT has major limitations in assessing LN metastasis, in identifying peritoneal dissemination, and in identifying small hematogenic metastases. Recently, tissue metabolism based FDG-PET has emerged as a promising new modality for tumor staging. The limited published experience with esophageal and gastric carcinomas suggests that FDG-PET is highly sensitive in detecting the primary tumor as well as distant metastases. The high sensitivity of PET in detecting the primary adenocarcinoma of the stomach was confirmed in this prospective study, which is consistent with several other reports.[15–17]

We observed several interesting results concerning the use of FDG-PET in detection of primary tumor. First, FDG uptake and sensitivity of PET for detecting primary tumor in early gastric cancer and in advanced gastric cancer were significantly different ($P < 0.05$). Second, we found a significant relation between SUV and primary tumor size. These results suggested that FDG uptake could be closely associated with tumor progression in gastric adenocarcinoma. Third, the mean SUV was higher in the tubular adenocarcinoma group than in the mucinous and signet ring cell adenocarcinoma group. This result has been demonstrated by several other reports.[18–20] It has been postulated that the low or absent FDG avidity in SRC resulted from the high content of metabolically inert mucus leading to a reduced FDG concentration. Another reason could be the lack of expression of the glucose transporter Glut-1 on the cell membrane of most SRC and mucinous adenocarcinoma.[21]

We found a significant difference between the primary tumor SUV and the extension of lymph node metastasis. Increased SUV of primary tumor always

correlated with lymph node metastasis, which was also observed by Mochikis et al.[17] FDG uptake is believed to be carried out by glucose transporters (Gluts), a significant increase in Glut-1 mRNA and protein has been described in tumors of the esophagus, stomach, and colon.[21–23] Positive correlations between Glut-1 expression and an increased incidence of lymph node metastasis in patients with colorectal and gastric carcinoma have been described.[21,23] Thus, increased FDG uptake in a primary tumor may be an indication of an increased risk of lymph node metastasis.

For an assessment of a local LN involvement, FDG-PET had a significantly higher specificity than CT (92% vs. 62%, $P = 0.000$) and a significantly lower sensitivity (56% vs. 78%, $P = 0.002$), although the overall accuracy of both modalities was similar (63% vs. 75%, $P = 0.115$). The lower sensitivity of FDG-PET for detecting a local LN was attributed to the limited spatial resolution of the PET scanner. Therefore, the low focal uptake of a local LN may not be separated from the primary lesion, which has intense tracer accumulation and ill-defined anatomical boundaries.[6] The limitation in detecting a local LN has been reported in that PET could not reliably distinguish between N0 and N1 disease.[8] However, it would not pose a potential management problem because a D2 resection (the removal of the N1 and N2 nodes with the primary tumor) is a routine procedure at our institute.

In contrast to the report by Yeung et al.,[16] which suggested that a lymph node distant from the stomach would theoretically be easier to identify on a FDG-PET scan, our study failed to show the advantage of FDG-PET for detecting distant LN metastasis compared to the CT scan. Although five false-positive and two false-negative results were noted in the CT scan results and only two false positive and one false negative in the PET results, this difference was not statistically significant. PET was able to correct the stage in four patients who had been inaccurately staged by CT preoperatively.

In patients with a peritoneal dissemination, FDG-PET had a strong tendency of low sensitivity compared with CT scan ($P = 0.063$). Although it is not statistically significant, this is in line with reports by Herrington et al.,[15] Yeung et al.,[16] and Jadvar et al.[24] False-negatives were found in 7 of 10 patients. From surgical observations, all these patients had small (< 5 mm) nodules of peritoneal seeding. The pathology showed mainly extensive fibrosis with a small number of malignant cells in the disseminated lesion. The actual tumor cells were too sparse and spread out to provide sufficient information for the PET scanner to detect. Although CT has a high sensitivity in detecting a peritoneal dissemination, it has a low specificity due to high false-positive findings. When detecting peritoneal carcinomatosis, CT can easily detect abnormal abdominal changes based on signs such as peritoneal caking, nodularity, beaded thickening, and malignant ascites.[25,26] Given that a positive diagnosis of these findings may lead to a false-positive result, laparoscopy was recently used to confirm the positive findings by CT. This is because this minimally invasive staging modality is quite sensitive in detecting small volume peritoneal metastases.[14] Distant metastasis is uncommon, but its detection is important when making a preoperative evaluation. Unfortunately, both FDG-PET and CT missed one hematogenic metastasis and produced false-positive results in a liver metastasis. Although the number was small, this suggests that neither an FDG-PET nor a CT scan alone is useful for detecting small hematogenic metastases. To reduce the incidence of unnecessary surgery, laparoscopic ultrasonography could be recommended.

Normal stomach may also demonstrate FDG uptake. In our experience, the uptake level is low and usually conforms to gastric configuration, and few of them have 2 points in our 3-point scale. Only Grades 2 and 3 were considered as positive to be included in this study in order to decrease the possibility of false positive results.

When interpreting the results of PET, one should consider that a false-positive diagnosis may prevent it from being safely applied. In our patients, PET overstaged one patient due to the false-positive FDG accumulation in the inflammatory local LN and liver (with cholecystitis). Another five false-positive diagnoses were made in the case of two distant LNs, one peritoneal dissemination, and two liver lesions. Therefore, despite its high positive predictive value, it is important to confirm the malignant nature of the lesion found by PET. This may lead to change in therapeutic management.

Based on these results, PET may play a complementary role in pretreatment evaluation. FDG-PET upstaged 4 (6%) patients from the false-negative CT findings. PET provided important information for making decisions regarding treatment. A splenectomy was performed in a patient who was later confirmed to have a spleen metastasis, and a D4 lymphadenectomy was performed in a patient who was later confirmed to have a No. 16, and No. 111 LN metastasis. FDG-PET downstaged 6 (9%) patients from CT false-positive findings. Therefore, those patients who benefited from the FDG-PET detection method were treated with a timely curative resection, without the need for any extra neoadjuvant chemotherapy.

In conclusion, FDG-PET appears to be a prospec-

tive method for making a preoperative evaluation of gastric adenocarcinoma. PET can provide important additional information concerning the preoperative staging of gastric adenocarcinoma. FDG-PET and CT are expected to play complementary roles, and together they should be able to increase the accuracy of preoperative staging. A further study on modifying the spatial resolution using radiotracers is needed to improve the sensitivity of local LN involvement and peritoneal dissemination and to fully integrate FDG-PET into routine staging of a gastric adenocarcinoma.

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