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Preoperative Use of PET/CT in Patients With Colorectal and Gastric Cancer and Its Impact on Treatment Decision Making

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The advantages of primary positron emission tomography–computed tomography (PET-CT) evaluation of both cancers needs to be clarified. This study aimed to investigate the efficacy of PET-CT compared with computed tomography (CT) in preoperative evaluation of colorectal and gastric cancer patients, and to determine its effects on treatment decision-making. We prospectively evaluated patients who presented with both types of cancer in our clinic between September 2008 and June 2010, using PET-CT and CT. We compared the results with histopathologic findings and determined the changing treatment strategies. In detecting local lymph node positivity, for colorectal cancer patients the sensitivity of PET-CT was 30% and that of CT was 20%; the specificities were the same (100%). For gastric cancer patients, the sensitivity of PET-CT was 38.9% and that of CT was 22%; the specificities were 100% and 83%, respectively. In detecting metastasis, for colorectal cancer patients the sensitivity of PET-CT was 80% and that of CT was 50%; the specificities were similar (100% versus 95%). For gastric cancer patients, the sensitivity of PET-CT was 72% and that of CT was 34%; the specificities were similar (95% versus 90%). In detecting liver metastasis, for colorectal cancer patients the

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sensitivity of PET was 75% and that of CT was 50%; the specificities were similar (100% versus 95%). For gastric cancer patients, the sensitivity of PET-CT was 57% and that of CT was 28%; the specificities were similar (95% versus 91%). PET-CT findings altered treatment decisions in 16% of patients (n = 10; 9 gastric cancer and 1 colorectal cancer). A high rate of treatment strategy alteration in gastric cancers was seen with PET-CT; its usage is preferred in colorectal cancer staging only for high-risk patients and those with equivocal findings.

Key words: Gastric cancer – Colorectal cancer – Preoperative use of PET/CT

Colorectal and gastric cancer are the two most commonly seen devastating gastrointestinal cancers. These types of cancer are, respectively, the third and fourth most common causes of cancer-related death. The mainstay of therapy for both is still oncologic radical surgery with supportive medical therapies. Preoperative evaluation is very important for the determination of initial treatment strategies. Moreover, satisfactory preoperative staging results in better survival, less local recurrence, and reduced morbidity and mortality.[1]

At the present time, conventional radiologic methods, such as computed tomography (CT), magnetic resonance imaging, and ultrasonography, are routinely used for preoperative staging of both cancers. Advanced CT techniques that use thin sections, optimal contrast material enhancement, and multiplanar reformation allow accurate staging in both cancers. However, these techniques also have some limitations and present difficulties in differentiating between benign fibrosis, malign tumors, and postoperative changes.[2] These limitations of CT lead to a lack of sensitivity and specificity in recognition, because CT's diagnostic ability is dependent only on the morphologic changes of the involved organs and distorted anatomic structures. These factors result in difficulties in image interpretation.[3]

Positron emission tomography–CT (PET-CT) has an important role in clinical oncology, where it is used as functional imaging. Unlike anatomic imaging, 18F-fluorodeoxyglucose (18F-FDG) PET may have a role in predicting patient prognosis on the basis of the metabolic activity of primary tumors. At staging, one of the major contributions of 18F-FDG PET is in the detection of unsuspected metastases, leading to changes in therapeutic plans for patients with various malignancies.[4] It involves an intravenous injection of a radioactive tracer (most commonly FDG), which is attached to a biologic tracer that distributes itself throughout the body in a recognized pattern. FDG is converted to FDG-6 phosphate by the action of a hexokinase similar to normal glucose. However, FDG is not further metabolized, and it remains trapped in the cell. As a tumor cell uses more glucose, FDG accumulates there within the cells.[5] PET-CT combines the metabolic functional information of PET with the anatomic information of CT, and this hybrid technique improves the diagnostic accuracy of cancer. Israel *et al*[6] demonstrated that 17% of cancer patients' clinical managements changed after scanning by hybrid systems.

PET-CT scans are used mainly for differentiation of equivocal morphologic findings, follow-up, therapy stratification and monitoring, postoperative recurrence, and also, in some rarely selected cases, preoperative imaging of both cancers. PET-CT evaluation has a higher accuracy rate than CT and PET alone in preoperative staging in gastric cancer.[7] It is recommended in recent guidelines[8] as an initial preoperative method. However, studies about the advantage of initial PET-CT evaluation are scarce, and controversy still exists regarding its usage in primary staging for gastric cancer.[9–11] PET-CT usage in preoperative staging of colorectal cancer is usually reserved for high-risk patients and for when there are equivocal findings in other radiologic modalities; it is not recommended as an initial diagnostic method in any guidelines. However, there are several recent reports that demonstrate improvements with PET-CT scans in the preoperative staging of colorectal cancer.[12–14]

Serum tumor biomarkers are the substances that are produced by the tumor or secreted by the tissue as a response to the tumor. They may be used in the prognostic assessment and following of recurrence and metastasis in cancer cases. Carcinoembryonic antigen (CEA) and CA 19-9 are the most studied tumor biomarkers that have been evaluated for the management of gastric and colorectal cancers.[15]

Our aim is to investigate the efficacy of PET-CT scans compared with CT scans and to do research for correlation between tumor markers and PET-CT images in preoperative evaluation of colorectal and gastric cancer patients, and to determine its effects on treatment decision-making.

Patients and Methods

Patients

Sixty-one patients who were referred for surgery to the Kartal Koşuyolu Yüksek İhtisas Research and Education Hospital Gastroenterological Surgery Clinic because of gastric and colorectal cancer between September 2008 and June 2010 were analyzed prospectively. All patients were examined prospectively with 18F-FDG PET-CT in our department before any planned interventions. Exclusion criteria included a second primary malignancy and active infection before the 18F-FDG PET-CT examination. The study was approved by the Education and Planning Committee of Kartal Koşuyolu Yüksek İhtisas Research and Education Hospital.

Results of biopsy specimens and preoperative tumor biomarker levels were recorded. They were accepted as high when serum CEA level was greater than 5 ng/mL and serum CA 19-9 level was greater than 37 U/mL. Standard spiral abdominal and thorax CT examinations were evaluated by the same radiologist. All of the patients underwent PET-CT evaluation. Of these, 54 patients underwent surgery. Seven patients were not eligible for surgery because of disseminated disease. Resected specimens were staged according to the 7th edition of the AJCC Cancer Staging Manual. Lymph node stages of pathologic specimens and metastasis findings were compared to the results of CT and PET-CT. Additionally, the results of the CT and PET-CT scans were compared to each other. Treatment strategy changes after PET-CT examination were evaluated.

PET-CT Imaging

Before PET-CT scanning, all patients fasted for at least 6 hours. Patients were confirmed to have blood sugar levels below 150 mg/mL and had rested for approximately 45 minutes before receiving an intravenous injection of 296 to 703 MBq of 18F-FDG. Oral contrasts were administered. Scanning began 60 minutes later. A combined PET-CT in-line system (Biograph mCT 64, Siemens Healthcare, Erlangen, Germany) was used for all data collection. CT scanning was performed from the orbitomeatal line to the upper thigh (30 mA; 130 kV; 5-mm–thick sections) prior to the PET scan. The PET scan was then immediately conducted over the same body region with 6 to 8 bed positions, with a 2-minute acquisition time per bed position. Lesions that had maximum standardized uptake value levels above 2.5 were accepted as malign.

Statistical analysis

Statistical Package and Software Solution 15.0 (SPSS 15.0, Chicago, Illinois) software was used for data entry and statistical calculations. According to the results of PET-CT, CT, and histopathologic examinations, the rates of detection of the primary tumor, distant metastasis, and lymph node metastasis were determined. The sensitivity, specificity, accuracy, positive predictive value, and negative predictive value were calculated. To analyze the association between preoperative tumor biomarkers and preoperative PET-CT images, Fisher exact test was performed. Statistical significance was assumed when a P value was less than 0.05. Also, the correlations between preoperative serum CEA or CA 19-9 levels and preoperative PET-CT images were analyzed by φ correlation coefficient test.

Results

Patient characteristics

A total of 61 patients were enrolled in the study. There were 30 patients (49.2%) with colorectal cancer, and 31 patients (50.8%) with gastric cancer. There were 37 men and 24 women, with a median age of 59.16 ± 11.3 years. A total of 61 patients had adenocarcinoma; 4 had signet ring cells; 3 were undifferentiated; and 1 had mucinous-type adenocarcinoma. Seven patients were found to have metastatic disease during the primary evaluation, and were directed to medical therapy. A total of 54 patients underwent oncologic radical resections. Patients' demographic data, serum tumor biomarker levels, imaging findings, pathologic staging of tumors, and therapeutic decisions are shown in Table 1.

Diagnostic ability of PET-CT and CT

All of the tumors were shown by CT, but 2 of the gastric cancers could not be shown by PET-CT. One of these was undifferentiated, and the other was signet ring cell–type adenocarcinoma (Table 1).

Table 1 Patients' demographic data, pathology, preoperative tumor biomarkers, imaging findings, and therapeutic decisions

Patient No.	Age, y	Sex	Diagnosis	Pathology	CEA (value), ng/mL	CA 19-9, U/mL	CT, TNM	PET-CT, TNM[a]	Pathology, TNM	Impact on therapeutic decision of PET-CT
1	74	M	Rectum	Mucinous	5.00	5.00	T3N0M1	N1M1	T_3N2M1	No
2	60	F	Gastric	Adenocarcinoma	1.00	99.00	T4N0M1	N1M0	T3N3M1	Yes
3	54	M	Gastric	Adenocarcinoma	0.00	7.00	$T_{1\text{-}2}$N1M0	N1M0	T2N2M1	No
4	72	F	Gastric	Signet ring cell	0.00		T3N0M0	N0M0	T3N2M0	No
5	63	F	Rectum	Adenocarcinoma	10.00	97.00	$T_{1\text{-}2}$N1M0	N1M0	T3N2M0	No
6	61	M	Colon	Adenocarcinoma	19.00	6.00	T3N0M1	N0M1	T4N0M1	No
7	73	M	Rectum	Adenocarcinoma	4.00	8.00	T4N0M1	N0M0	T3N2M0	Yes
8	66	F	Colon	Adenocarcinoma	9.00	29.00	$T_{1\text{-}2}$N0M0	N0M0	T3N0M0	No
9	71	M	Gastric	Adenocarcinoma	2.00	24.00	$T_{1\text{-}2}$N0M0	N0M0	T2N0M0	No
10	67	F	Colon	Adenocarcinoma	3.00	8.00	T3N0M1	N1M1	T3N2M1	No
11	38	M	Rectum	Adenocarcinoma	5.00	46.00	$T_{1\text{-}2}$N0M1	N0M1	T3N2M1	No
12	54	M	Gastric	Undifferentiated	2.00	13.00	$T_{1\text{-}2}$N0M0	NE[b]	T1N0M0	No
13	58	M	Colon	Adenocarcinoma			$T_{1\text{-}2}$N0M0	N0M0	T3N1M0	No
14	68	M	Gastric	Adenocarcinoma	2.00	10.00	T3N0M0	N0M0	T3N2M0	No
15	75	F	Rectum	Adenocarcinoma	10.00	122.00	T3N1M0	N0M1	T3N1M1	No
16	78	F	Colon	Adenocarcinoma		14.00	T3N0M0	N0M0	T3N0M0	No
17	48	F	Colon	Adenocarcinoma		27.00	T3N0M0	N0M0	T3N1M0	No
18	65	F	Colon	Adenocarcinoma	1.00	9.00	T4N0M0	N1M1	T3N2M1	No
19	63	M	Gastric	Adenocarcinoma		23.00	T3N0M0	N1M0	T3N2M0	No
20	56	M	Gastric	Adenocarcinoma	6.00		T3N1M0	N0M0	T3N2M0	No
21	72	M	Colon	Adenocarcinoma	1.00	4.00	$T_{1\text{-}2}$N0M0	N0M0	T3N1M0	No
22	72	F	Colon	Adenocarcinoma	9.00	10.00	$T_{1\text{-}2}$N0M0	N0M0	T3N0M0	No
23	68	F	Rectum	Adenocarcinoma	124.00	257.00	T3N1M0	N1M1	T3N2M1	No
24	63	F	Gastric	Adenocarcinoma	6.00	2.00	T3N0M0	N1M0	T3N1M0	No
25	53	F	Gastric	Adenocarcinoma	11.00	11.00	$T_{1\text{-}2}$N0M0	N0M0	T2N0M0	No
26	52	M	Gastric	Adenocarcinoma			$T_{1\text{-}2}$N0M0	N1M0	T3N2M0	No
27	64	M	Gastric	Adenocarcinoma			T3N0M0	N0M0	T3N3M0	No
28	73	F	Gastric	Adenocarcinoma	1.00	11.00	T3N1M0	N1M0	T2N0M0	No
29	69	M	Gastric	Adenocarcinoma	1.00	1.00	$T_{1\text{-}2}$N0M1	N0M1	T1N0M0	No
30	39	M	Gastric	Adenocarcinoma	13.00		T3N0M0	N0M0	T3N3M0	No
31	72	F	Rectum	Adenocarcinoma	2.00	57.00	T4N0M0	N1M0	T3N1M0	No
32	57	M	Gastric	Adenocarcinoma	1.00		$T_{1\text{-}2}$N0M0	N0M0	T3N1M1	No
33	47	M	Gastric	Signet ring cell	1.00	6.00	$T_{1\text{-}2}$N0M0	NE[b]	T3N0M0	No
34	57	M	Colon	Adenocarcinoma	1.00	14.00	T3N0M0	N0M0	T3N1M1	No
35	63	M	Colon	Adenocarcinoma	3.00	69.00	$T_{1\text{-}2}$N0M0	N0M0	T3N1M0	No
36	59	M	Rectum	Adenocarcinoma	2.00	4.00	T3N0M0	N0M0	T3N2M1	No
37	64	M	Rectum	Adenocarcinoma	100.00	120.00	T4N0M0	N0M0	T4N1M0	No
38	59	M	Colon	Adenocarcinoma	2.00	5.00	T3N0M0	N0M0	T3N0M0	No
39	38	F	Gastric	Signet ring cell	1.00	28.00	$T_{1\text{-}2}$N0M0	N0M0	T2N1M0	No
40	74	M	Gastric	Undifferentiated	1.00	17.00	$T_{1\text{-}2}$N1M0	N0M0	T3N1M0	No
41	63	M	Gastric	Adenocarcinoma	4.00	69.00	$T_{1\text{-}2}$N0M0	N0M0	T3N1M0	No
42	53	M	Rectum	Adenocarcinoma	1.00	17.00	T3N0M0	N0M0	T3N0M0	No
43	38	F	Colon	Adenocarcinoma	0.00	27.00	$T_{1\text{-}2}$N0M0	N0M0	T3N0M0	No
44	53	F	Rectum	Adenocarcinoma	5.00	6.00	T3N0M0	N0M0	T3N1M0	No
45	66	F	Gastric	Adenocarcinoma	0.00	3765.00	T3N0M0	N0M0	T3N1M0	No
46	52	M	Gastric	Adenocarcinoma	18.00	9.00	T4N0M1	N1M1	T4N2M1	No
47	34	F	Rectum	Adenocarcinoma	5.00	28.00	T4N0M1	N0M1	T4N2M1	No
48	45	M	Gastric	Adenocarcinoma	2.00	119.00	T4N1M1	N1M0	T4N2M0	Yes
49	37	M	Rectum	Adenocarcinoma	1.00	26.00	T3N0M0	N0M0	T3N0M0	No
50	57	M	Gastric	Adenocarcinoma	2.00	14.00	$T_{1\text{-}2}$N0M0	N0M0	T3N2M0	No
51	61	M	Colon	Adenocarcinoma	4.00	17.00	T3N1M0	N0M0	T3N1M0	No
52	75	F	Colon	Adenocarcinoma	2.00	8.00	$T_{1\text{-}2}$N0M0	N0M0	T3N0M0	No
53	72	F	Colon	Adenocarcinoma	4.00	13.00	T3N0M0	N0M0	T3N0M0	No
54	58	F	Colon	Adenocarcinoma	6.00	21.00	T3N0M0	N0M0	T4N2M0	No
55	49	M	Gastric	Adenocarcinoma	41.00	516.00	T3N0M0	N1M1	—	Yes
56	51	M	Gastric	Undifferentiated	4.00	4.00	T3N1M0	N1M1	—	Yes
57	34	F	Gastric	Adenocarcinoma	7.00	2.00	T3N0M0	N0M1	—	Yes
58	51	M	Gastric	Signet ring cell	2.00		$T_{1\text{-}2}$N0M0	N1M1	—	Yes

Table 1 Continued

Patient No.	Age, y	Sex	Diagnosis	Pathology	CEA (value), ng/mL	CA 19-9, U/mL	CT, TNM	PET-CT, TNM[a]	Pathology, TNM	Impact on therapeutic decision of PET-CT
59	55	M	Gastric	Adenocarcinoma	2.00	330.00	T3N0M1	N0M1	—	Yes
60	65	M	Gastric	Adenocarcinoma	120.00	233.00	T3N0M1	N1M1	—	Yes
61	61	M	Gastric	Adenocarcinoma	35.00	5.00	T3N0M0	N0M1	—	Yes

NE, not evaluated; —, not done.

[a]T stage not evaluated on PET-CT.

[b]PET-CT negative.

Of the 54 patients who underwent radical resection, 38 had lymph node metastasis. There were 8 patients and 13 patients who had lymph node metastasis that was detected by CT and PET-CT scan, respectively. Sensitivities were 21% and 34%, respectively (Tables 2 and 3). When these patients were evaluated separately, 20 of 30 colorectal patients had lymph node metastasis, and 4 patients and 6 patients with colorectal metastasis had it detected by CT and PET-CT, respectively. There were no false-positive results in either of these modalities. The sensitivities of CT and PET-CT were 20% and 30%, respectively. Specificity was 100% with both of the modalities. A total of 18 of 24 gastric cancer patients had lymph node metastasis, and 4 patients and 7 patients with lymph node metastasis had it detected by CT and PET-CT, respectively. One patient who had no lymph node metastasis was shown to have lymph node metastasis by CT. The sensitivities of CT and PET-CT were 22.2% and 38.9%, and the specificities were 83% and 100%, respectively (Table 4).

A total of 21 of 61 patients had metastasis: 12 isolated liver, 2 bone, 1 ovary, 1 lung, 2 lung and bone, 2 liver and lung, and 1 lung and liver metastases were detected. When these patients were evaluated separately, 10 of 30 colorectal patients had metastatic disease. A total of 5 patients and 8 patients who had metastatic disease had it detected by CT and PET-CT, respectively. One patient was falsely evaluated as having metastatic disease by CT. The sensitivities of CT and PET-CT were 50% and 80%, and the specificities were 95% and 100%, respectively. A total of 11 of 30 gastric patients had metastatic disease. There were 4 patients and 8 patients with metastatic disease who had it detected by CT and PET-CT, respectively. There were 2 patients and 1 patient who were falsely evaluated as having metastatic disease by CT and PET-CT, respectively. The sensitivities of CT and PET-CT were 36.4% and 72.7%, and the specificities were 90% and 95%, respectively (Tables 5–7).

When all patients with liver metastasis were evaluated separately, liver metastasis was detected in 15 patients. A total of 6 patients and 10 patients with liver metastasis had it detected by CT and PET-CT, respectively. The sensitivities of CT and PET-CT were 40% and 66%, and the specificities were 94% and 98%, respectively.

The correlation between preoperative tumor biomarkers and preoperative PET-CT images

The association between preoperative serum CEA and preoperative PET-CT images was statistically significant ($P < 0.05$). The serum CEA level was reported to be greater than 5 ng/mL in 64.7% of PET-positive patients. The serum CEA level was reported to be greater than 5 ng/mL in 26.3% of PET-negative patients. Also, φ correlation coefficient was recorded as 0.365. The association between

Table 2 Lymph node metastasis on CT

	CT		
	N(−)	N(+)	Total, n
Pathology, n (%)			
N(−)	15 (93.8)	1 (6.3)	16
N(+)	30 (78.9)	8 (21.1)	38
Total, n	45	9	54

Table 3 Lymph node metastasis on PET-CT

	PET-CT		
	N(−)	N(+)	Total, n
Pathology, n (%)			
N(−)	16 (100)	0	16
N(+)	25 (65.8)	13 (34.2)	38
Total, n	41	13	54

Table 4 Lymph node metastasis, positive predictive value (PPV), and negative predictive value (NPV)

	Sensitivity	Specificity	False negative	False positive	PPV	NPV
CT, %	21	94	78	6	88	33
PETCT, %	34	100	65	0	100	39

preoperative serum CA 19-9 and preoperative PET-CT images was statistically significant ($P < 0.05$). The serum CA 19-9 level was reported to be greater than 5 U/mL in 41.2% of PET-positive patients. The serum CA 19-9 level was reported to be greater than 5 U/mL in 15.9% of PET-negative patients. Also, φ correlation coefficient was recorded as 0.269 (Table 8).

Clinical impact of PET-CT on patient management

PET-CT results had an impact on the management of 10 (16.4%) of the 61 patients. Nine of these patients had gastric cancer, and the other patient had colorectal cancer. Of the 10 patients, 7 were directed to medical therapy, and 3 were referred to radical surgery. The 7 patients referred to medical therapy had distant metastases: 2 of them had lung and bone, 2 had only bone, 1 had lung and liver, and 2 had liver and bone. The 3 patients who were referred to surgery had equivocal findings with CT, but PET-CT showed no FDG uptake. Two of them had gastric cancer, one had liver cancer, and the other was suspected of having lung metastasis. One patient was suspected of having colon cancer and liver metastasis (Tables 9 and 10).

A total of 13 patients (21%) had discordant findings between CT and PET-CT. CT did not show distant metastasis, whereas PET-CT showed metastasis in 8 patients. In addition, PET-CT did not show lesions in 5 patients. Two of these patients had undifferentiated tumors that had no FDG uptake. The other 3 patients had equivocal metastatic findings that could not be confirmed by PET-CT (Table 11).

Table 5 Distant metastasis on CT

	CT		
	M(−)	M(+)	n
Metastasis, n (%)			
M(−)	37 (92.5)	3 (7.5)	40
M(+)	12 (57.1)	9 (42.9)	21
Total, n	49	12	61

Table 6 Distant metastasis on PET-CT

	PET-CT		
	M(−)	M(+)	n
Metastasis, n (%)			
M(−)	39 (97.5)	1 (2.5)	40
M(+)	5 (23.8)	16 (76.2)	21
Total, n	44	17	61

Discussion

Proper staging of the neoplastic process plays a key role in determining subsequent therapeutic management. Preliminary determination of the local tumor stage constitutes the basis for referral to surgical treatment. However, identification of distant metastasis shifts patients to the palliative treatment group.[16] CT still has an important role for this purpose, but with some limitations.

The routine use of 18-FDG PET-CT in the imaging of gastrointestinal system malignancies has been increased in the last decade.[17] This imaging technique could help to discriminate between resectable and unresectable disease, and prevent unnecessary surgical procedures. In some cases, the prognostic value of PET-CT and its role in chemotherapy response evaluation have been demonstrated. On the other hand, its role in primary staging is controversial.

In our study, for imaging of a primary tumor, positive FDG uptake identified 93% of gastric and 100% of colorectal cancer patients. Similar rates[11,18] are usually observed in other gastric cancer studies, but lesser rates (60%) were also observed.[19] Signet ring cell and mucinous carcinomas express very low levels of GLUT-1 (glucose transporter 1) receptor and 18F-FDG uptake mostly related to this receptor's levels.[7] Additionally, early gastric cancer has a very low detection rate of 20%.[19] Only 2 of the 8 gastric tumors with low affinity did not uptake FDG in our series. Five patients (8%) had stage I cancer; thus, staging had no influence on our results.

In detecting local lymph node positivity, the sensitivity of PET-CT was higher than that of CT

Table 7 Distant metastasis, positive predictive value (PPV), and negative predictive value (NPV)

	Sensitivity	Specificity	False negative	False positive	PPV	NPV
CT, %	43	93	57	7	75	75
PET-CT, %	76	98	23	2	94	88

Table 8 The correlation between preoperative serum tumor biomarkers and preoperative PET-CT

	PET-CT positive, n (%)	PET-CT negative, n (%)	P^a	Phi	P^b
CEA					
CEA <5 ng/mL	28 (73.7)	6 (35.3)			
CEA >5 ng/mL	10 (26.3)	11 (64.7)	0.015*	0.365	0.007**
CA 19-9					
CA 19.9 <37	37 (84.1)	10 (58.8)			
CA 19.9 >37	7 (15.9)	7 (41.2)	0.047*	0.269	0.035*

[a]Fischer exact test *P* value.

[b]Phi and Cramer's test *P* value.

*$P < 0.05$.

**$P < 0.01$.

(30% versus 20%), but the specificity was same (100% versus 100%) for colorectal cancer patients. Similarly, the sensitivity of PET-CT was higher than that of CT (38.9% versus 22%), and the specificity was higher as well (100% and 83%, respectively) for gastric cancer patients. Lymph node assessments done by CT scan and PET-CT were unreliable, as they were in other studies that focused on colorectal and gastric cancers. This is because the diagnostic performance of 18F-FDG PET for lymph node staging seems dependent on many factors, such as the avidity of primary tumors for 18F-FDG, the frequency of lymph node metastasis, and the size of metastatic lymph nodes.[4] In the literature, the PET-CT sensitivities of lymph node metastasis for gastric and colon cancer have been reported as 30% to 64% and 28% to 37%, respectively.[13,14,17,19] PET-CT specificity has been reported as 94% to 100% for gastric cancer patients, and 83% to 96% for colon cancer patients.[14,17,19] Lymph node detection scores by CT were 22% to 84% for colon cancer,[14] and 25% to 78% for gastric cancer.[17,18] Usually, lower lymph node positivity sensitivity but higher lymph node positivity accuracy rates were observed with PET-CT for both cancers.[20,21] Combined FDG PET-CT systems can localize primary tumor and lymph nodes more precisely, and give anatomic and functional information together. Because FDG PET-CT diagnoses lymph node metastasis using glucose metabolism rather than size change, it is very useful in distinguishing enlarged lymph nodes due to inflammation from cancer cell metastasis.[14] Thus, PET-CT has a very low false-positive result rate in these two most common gastrointestinal malignancies; however, probably because of high FDG uptake by the primary tumor, its sensitivity is low.

Table 9 Effect of PET-CT on treatment plan

	Diagnosis		
	Colorectal	Gastric	Total
Impact on decision (PET-CT), n			
Not changed	29	22	51
Medical→surgery	1	2	3
Surgery→medical	0	7	7
Total, n	30	31	61

It remains unclear whether monitoring serum tumor biomarkers has any clinical benefit in the management of colorectal and gastric cancer patients. Serum CEA and CA 19-9 are not recommended as a screening test, but such a test might be ordered preoperatively if it can assist in staging. Previous reports showed a significant association between elevated serum CA 19-9 or CEA levels and poor prognosis related to disease stage in the preoperative settings.[22] Zheng *et al*[23] found that patients with advanced-stage colorectal cancers had significantly increased levels of CEA and CA 19-9. However, in the literature, especially in studies in patients with gastric cancer, a correlation between increased CEA or CA 19-9 and advanced stage was not found.[15] Therefore, in the present study we want to evaluate the preoperative CEA and CA 19-9 values along with PET-CT images in colorectal and gastric cancer patients. In our study, we found that high levels of both CEA and CA 19-9 associated with PET-CT positive patient images, and this was statistically significant as well. The positivities for both tumor markers are able to be an important indicator of advanced stage in gastric and colorectal patients.

There were 10 colorectal and 11 gastric cancer patients with metastatic disease in our study. In detecting metastasis, the sensitivity of PET-CT was higher than that of CT (80% versus 50%), but the specificity was similar (100% versus 95%), for colorectal cancer patients. Similarly, for gastric cancer patients the sensitivity of PET-CT was higher than that of CT (72% versus 34%) and the specificity was similar (95% versus 90%). A total of 8 colorectal and 7 gastric cancer patients had liver metastasis. In detecting liver metastasis, the sensitivity of PET was higher than that of CT (75% versus 50%), but the specificity was similar (100% versus 95%), for colorectal cancer patients. Similarly, the sensitivity of PET-CT was higher than that of CT (57% versus 28%), and also specificity was similar (95% versus 91%), for gastric cancer patients. Kinkel *et al*[24] also

Table 10 Changing treatment plans of patients

Patient no.	Age, y/sex	Diagnosis	CT TNM	PET-CT TNM[a]	Impact on therapeutic plan (PET-CT)
2	60/F	Gastric	T4N0M1	N1M0	Medical→surgery (T3N3M1)
7	73/M	Colorectal	T4N0M1	N0M0	Medical→surgery (T3N2M0)
48	45/M	Gastric	T4N1M1	N1M0	Medical→surgery (T4N2M0)
55	49/M	Gastric	T3N0M0	N1M1	Surgery→medical
56	51/M	Gastric	T3N1M0	N1M1	Surgery→medical
57	34/F	Gastric	T3N0M0	N0M1	Surgery→medical
58	51/M	Gastric	T_{12}N0M0	N1M1	Surgery→medical
59[b]	55/M	Gastric	T3N0M1	N0M1	Surgery→medical
60[b]	65/M	Gastric	T3N0M1	N1M1	Surgery→medical
61	61/M	Gastric	T3N0M0	N0M1	Surgery→medical

[a]T stage not evaluated with PET-CT.

[b]Suspicious lesion with CT.

showed that results of pairwise comparison between imaging modalities demonstrated a greater sensitivity of FDG PET than ultrasound, CT, and magnetic resonance imaging, with 90% sensitivity for colorectal, gastric, and esophageal cancers in their meta-analyses. Chung *et al*[25] found that FDG PET-CT imaging was able to detect solid organ metastasis (lungs, liver, bone, or adrenal gland) with a sensitivity of 95.2% and a specificity of 100%. In addition, Chua *et al*[26] showed isolated liver metastasis with 94% sensitivity and 75% specificity by FDG PET-CT in colorectal cancer patients, whereas the CT scan had 91% sensitivity and 25% specificity. Similar to other studies in the literature, we found that PET-CT had higher sensitivity rates for both hepatic and extrahepatic metastasis in our study. In addition, the specificity rates of PET-CT and CT were similarly high.

In our study, the PET-CT scan altered treatment decisions in 16% of patients (n = 10; 9 gastric cancer and 1 colorectal cancer). Similar results were observed in other studies as well. The treatment strategies changed between 16% and 35% in gastrointestinal cancers after PET-CT imaging was performed.[12,26–28]

Usually FDG PET-CT in the initial staging of colorectal cancer is reserved for high-risk patients (*e.g.*, those with raised CEA levels >10 ng/mL,

Table 11 The patients have discordance between CT and PET-CT

Patient No.	Age, y/sex	Diagnosis	CT/PET-CT uyum	CT finding	PET-CT finding	Pathology
2	60/F	Gastric	CT (+) PET-CT (−)	Liver metastasis suspicious	Normal PET-CT	No metastasis
7	73/M	Colorectal	CT (+) PET-CT (−)	Liver metastasis suspicious	Normal PET-CT	No metastasis
12	54/M	Gastric	CT (+) PET-CT (−)	Primary tumor	False negative	Undifferentiated
33	47/M	Gastric	CT (+) PET-CT (−)	Primary tumor	False negative	Signet ring
48	45/M	Gastric	CT (+) PET-CT (−)	Liver metastasis suspicious	Normal PET-CT	No metastasis
15	75/F	Colorectal	CT (−) PET-CT (+)	No finding	Liver metastasis	Adenocarcinoma metastasis
18	65/F	Colorectal	CT (−) PET-CT (+)	No finding	Ovarian mass	Adenocarcinoma metastasis
23	68/F	Colorectal	CT (−) PET-CT (+)	No finding	Liver metastasis	Adenocarcinoma metastasis
55	49/M	Gastric	CT (−) PET-CT (+)	No finding	Bone and liver metastasis	Inoperable
56	51/M	Gastric	CT (−) PET-CT (+)	No finding	Pulmonary and bone metastasis	Inoperable
57	34/F	Gastric	CT (−) PET-CT (+)	Primary tumor	Bone metastasis	Inoperable
58	51/M	Gastric	CT (−) PET-CT (+)	Primary tumor	Bone metastasis	Inoperable
61	61/M	Gastric	CT (−) PET-CT (+)	No finding	Bone and liver metastasis	Inoperable

locally advanced disease, or equivocal findings with conventional imaging).[29] In our study, the PET-CT scan changed the treatment strategy of 1 of 30 colorectal cancer patients. This patient had a false-positive hepatic metastasis in the CT scan. At the same time, PET-CT mostly changed the treatment protocol of the gastric cancer patients (29%) in our study. PET-CT is useful, especially in detecting solid organ metastasis for preoperative staging in gastric cancer patients[19,26]; however, anatomic imaging techniques for determination of the N and T stages remain as a standard recommendation.[25] PET-CT scans also have an advantage due to the radiotracer, because it is distributed throughout the body and larger volumes can be more easily scanned than is practical with CT.[26]

Conclusion

Similarly to previous studies, we found that gastric cancer patients gained more advantages with PET-CT scanning during primary staging compared with colorectal patients. In conclusion, a high rate of treatment strategy alteration in gastric cancers advocates its preoperative usage aggressively, and it should be done in all patients before performing surgery for gastric cancer, even with lower sensitivity, in neoplasms such as mucinous and undifferentiated types. Also, its usage is preferred in colorectal cancer staging preoperatively, especially for patients with increased CEA and CA 19-9 levels.

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