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Original Research

FDG PET/CT vs Staging Laparoscopy for Occult Metastases in Locally Advanced Gastric Adenocarcinoma: A Prospective Comparative Diagnostic Study

Jubaraj Kalita	Department of Surgical Oncology, IMS and SUM Hospital, Bhubaneswar, Odisha, India.
Snehasis Pradhan	Department of Surgical Oncology, IMS and SUM Hospital, Bhubaneswar, Odisha, India.
Sudam Sadangi	Department of Surgical Oncology, IMS and SUM Hospital, Bhubaneswar, Odisha, India.
Varun Joshi, Dr	Department of Surgical Oncology, IMS and SUM Hospital, Bhubaneswar, Odisha, India.
Shyam Kumar Hariharan	Department of Surgical Oncology, IMS and SUM Hospital, Bhubaneswar, Odisha, India.
Sangram Keshari Panda	Department of Surgical Oncology, IMS and SUM Hospital, Bhubaneswar, Odisha, India.
Sudatta Ray	Department of Nuclear Medicine, IMS and SUM Hospital, Bhubaneswar, Odisha, India.
Twinkle Rout	Department of Surgical Oncology, IMS and SUM Hospital, Bhubaneswar, Odisha, India.
Sunil Agrawala	Department of Surgical Oncology, IMS and SUM Hospital, Bhubaneswar, Odisha, India.

Introduction: Gastric cancer is an aggressive malignancy with a high risk of peritoneal spread. Accurate staging is critical to optimize treatment strategies and avoid unnecessary laparotomies. While PET-CT provides information on nodal and distant disease, staging laparoscopy allows direct visualization of peritoneal and liver involvement.

Materials and Methods: This was a prospective; single-centre diagnostic study conducted at IMS & SUM Hospital, Bhubaneswar, including 42 consecutive patients with newly diagnosed, locally advanced, non-metastatic gastric adenocarcinoma (cT3–4a, N0–3, M0). All patients underwent baseline contrast-enhanced CT, followed by both PET-CT and staging laparoscopy with peritoneal wash cytology. The primary endpoint was paired sensitivity of PET-CT versus staging laparoscopy in detecting peritoneal disease. Diagnostic yield and detection rates were compared.

Results: Among 42 patients (73.8% male; median age 57 years), staging laparoscopy identified peritoneal disease in 9/42 (21.4%, 95% CI 10.9–36.9), whereas PET-CT detected none (0/42; McNemar $p < 0.001$). PET-CT demonstrated perigastric nodal uptake in 37/42 (88.1%, 95% CI 74.4–95.6), but nodal status could not be confirmed pathologically. Staging laparoscopy detected liver metastases in 2/42 (4.7%) and omental deposits in 6/42 (14.2%), all of which were missed on PET-CT. Histopathology of M1 cases revealed poorly differentiated variants, predominantly signet ring and mucinous adenocarcinoma. Overall, staging laparoscopy altered management in 16/42 (43%) patients by redirecting them to neoadjuvant chemotherapy or palliative care.

Conclusions: PET-CT alone is inadequate for detecting peritoneal disease in locally advanced gastric cancer. Staging laparoscopy remains indispensable, especially in poorly differentiated

tumors, and significantly impacts treatment planning. Integration of PET-CT with staging laparoscopy provides the most reliable approach for accurate staging and optimal patient management.

Introduction

Gastric cancer, primarily adenocarcinomas (accounting for 90% of cases), is one of the leading causes of cancer-related mortality worldwide. Its incidence varies significantly by region, with higher rates observed in East Asia, South America, and Eastern Europe compared to Western Europe and the United States. This cancer predominantly affects men, with occurrence peaking in the seventh decade of life, and shows an inverse correlation with socioeconomic status [1-3]. Multiple risk factors contribute to its development, such as *Helicobacter pylori* infection, smoking, alcohol intake, dietary influences, atrophic gastritis, Epstein-Barr virus infection, and genetic predispositions. Gastric cancers are anatomically classified as either proximal or distal, with an increasing incidence of proximal tumours.

Microscopically, they are categorized into diffuse or intestinal types based on the Lauren classification. Staging is crucial for accurate diagnosis and treatment, with advanced imaging modalities like CT, MRI, EUS, PET-CT, and staging laparoscopy (SL) playing essential roles in clinical assessment. SL is particularly effective in identifying peritoneal spread, reducing unnecessary surgeries, and facilitating earlier chemotherapy. PET-CT scans, utilizing 18F-fluorodeoxyglucose (FDG), provide valuable metabolic data, enhancing the evaluation of staging, metastasis detection, and monitoring for recurrence, thus improving the management of advanced gastric cancer. This prospective single-center diagnostic study aimed to compare. PET-CT and staging laparoscopy in patients with locally advanced gastric adenocarcinoma, focusing on (i) paired sensitivity for detecting peritoneal disease, and (ii) the rate of management change attributable to staging laparoscopy.

Materials and Methods

This was a prospective observational study conducted in the Department of Surgical Oncology at IMS & SUM Hospital, Bhubaneswar, Odisha. All consecutive patients with newly diagnosed, non-metastatic, locally advanced gastric cancer who presented between 2021 and 2024 were evaluated. The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants.

Eligible patients were required to be older than 18 years and to have histologically confirmed adenocarcinoma of the stomach or esophagogastric junction (Siewert type III) diagnosed by gastroscopy. Only patients with surgically resectable, locally advanced gastric cancer (cT3–4a, N0–3, M0) as determined by a multidisciplinary tumor board were included. Patients were excluded if they had Siewert type I–II gastroesophageal junction tumors, had received prior neoadjuvant therapy, had recurrent or metastatic gastric cancer, or were deemed unfit or unwilling to undergo surgery.

All patients underwent baseline clinical evaluation, routine hematological and biochemical investigations, and contrast-enhanced CT (CECT) for initial staging. Subsequently, they underwent both PET-CT and staging laparoscopy with peritoneal wash cytology before treatment planning. The overall study protocol adhered to international guidelines with minor modifications to suit institutional feasibility.

For PET-CT, all patients fasted for at least six hours before the scan. A standard intravenous dose of 18F-fluorodeoxyglucose (18F-FDG) at 5 MBq/kg (0.14 mCi/kg) body weight was administered,

and blood glucose levels were confirmed to be below 180 mg/dl before injection. Imaging was performed 60 minutes after tracer administration, covering the region from the skull base to the mid-thigh, using a dedicated PET-CT scanner. Both low-dose non-contrast CT and contrast-enhanced diagnostic CT were obtained for anatomical correlation and attenuation correction. The images were independently interpreted by two experienced nuclear medicine physicians who were blinded to the laparoscopic findings.

Staging laparoscopy was performed under general anesthesia using a standard three-port technique. A systematic inspection was carried out to evaluate the liver surface, diaphragm, omentum, pelvis, and peritoneal reflections. Peritoneal wash cytology was obtained by instilling 200 ml of normal saline into the subphrenic and pelvic cavities, followed by aspiration for cytological evaluation. Any suspicious peritoneal or omental nodules were biopsied and sent for histopathological assessment. Cytology smears were prepared, fixed in alcohol, and stained using the Papanicolaou and Giemsa methods, and cell blocks were prepared when required.

The sample size was calculated based on an expected prevalence of peritoneal metastases in 20% of locally advanced gastric cancer cases in the Indian population, with $\alpha = 0.05$ and a power of 80%. A minimum of 42 patients was required, and this number was achieved. Statistical analysis was conducted using SPSS version 27 (IBM Corp., USA). Diagnostic accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of PET-CT and staging laparoscopy were calculated. Continuous variables were expressed as mean ± standard deviation, while categorical variables were summarized as percentages (Figure 1).

Figure 1. Flowchart of Patient Selection.

Study Protocol

In our study we followed protocol as below [1, 2] (Figure 2).

Figure 2. Study Flowchart. CT, computed tomography; CT3-4, advanced tumor with clinical T-stage 3 or 4; MDT,Multidisciplinary Team; PET, fluorodeoxyglucose position emission tomography with CT; SL, Staging Laparoscopy.

Results

A total of 42 patients with locally advanced, non-metastatic gastric cancer were included in the study. The majority were male (73.8%, n = 31), with a mean age of *\[insert mean ± SD]* years. Clinical staging distribution was as follows: cT2N0M0 in 11.9% (n = 5), cT2N+M0 in 26.1% (n = 11), cT3N+M0 in 42.8% (n = 18), and cT4aN+M0 in 19.1% (n = 8) (Table 1).

Variable	Category	No. of Patients	Percentage (%)
Sex Distribution	Male	31	73.8
	Female	11	26.1
Clinical Stage	cT2N0M0	5	11.9
	cT2N+M0	11	26.1
	cT3N+M0	18	42.8
	cT4aN+M0	8	19.1
Histopathological Diagnosis	Well Differentiated	6	14.2
	Moderately Differentiated	13	30.9

	Poorly Differentiated	18	42.8
	Undifferentiated	5	11.9
Subsite of Primary Tumor (Epicenter)	Distal Stomach (Antro Pyloric)	29	69.1
	GE Junction	6	14.2
	Body (Greater Curvature)	3	7.1
	Lesser Curvature	4	9.5
Nodal Status Detection	Perigastric Nodes via PET Scan	37	88.1
	Perigastric Nodes via Laparoscopy	8	19.1
Peritoneal Disease Detection	Detected via PET Scan	0	0
	Detected via Staging Laparoscopy	9	21.4
Peritoneal Wash Fluid Cytology	Positive for Malignancy	4	9.6
	Negative for Malignancy	38	90.4
Distant Metastasis (Excl. Peritoneal Disease)	Detected via Staging Laparoscopy	2	4.7
	Not Present	40	95.2

Table 1. Clinicopathological Characteristics and Diagnostic Findings of the Study Cohort.

On PET-CT, 52.3% (n = 22) of patients were classified as cT3. However, staging laparoscopy revealed that 4 of these 22 cases (18%) were actually cT4a, which had been under-staged on PET-CT. Histopathology of these misclassified patients showed poorly differentiated variants: signet ring cell type in 3 patients (75%) and mucinous adenocarcinoma in 1 patient (25%). PET-CT and laparoscopy findings were concordant for cT2 cases. Perigastric nodal involvement was detected in 88.1% (n = 37) of patients on PET-CT, with significant SUVmax uptake. In contrast, only 19.1% (n = 8) of patients had visible perigastric nodes during laparoscopy. No correlation was observed between nodal PET uptake and tumor histopathology. Staging laparoscopy identified peritoneal disease in 21.4% (n = 9) of patients, all of whom had been staged as M0 on PET-CT. Omental deposits were found in 14.2% (n = 6) patients, including 3 (7.2%) with isolated omental deposits. Liver metastases were detected in 4.7% (n = 2) patients on laparoscopy but missed on PET-CT. Overall, 23.8% (n = 10) patients were reclassified as M1 after laparoscopy. Histopathology revealed poorly differentiated adenocarcinoma with signet ring variant in 5 (11.9%), mucinous adenocarcinoma in 4 (9.5%), and undifferentiated carcinoma in 1 (2.3%) of these M1 cases. Staging laparoscopy findings altered the treatment plan in 43% (n = 16) of patients. These changes included shifting from upfront surgery to neoadjuvant chemotherapy or palliative management based on detection of peritoneal or liver metastases and reclassification of T stage.

Poorly differentiated and undifferentiated histologies accounted for 23/42 (54.7%). (Table 1).

The detection of perigastric nodal disease was significantly higher with PET-CT (88.1% vs. 19.1%, $p < 0.001$), whereas peritoneal disease detection was significantly higher with staging laparoscopy (21.4% vs. 0%, $p < 0.001$).

Sensitivity of PET-CT for peritoneal disease was 0% (0/9), specificity 100% (33/33). SL identified superficial liver deposits in 2/42 (4.7%), both missed on PET- CT. Overall, SL altered management in 18/42 (43%) patients. The main reasons were detection of peritoneal disease (9/42, 21.4%), positive cytology (4/42, 9.5%), or superficial liver metastases (2/42, 4.7%). In three cases, equivocal PET findings were clarified by SL, changing intent from curative to palliative (Table 2).

	SL/cytology +	SL/cytology –	Total
PET-CT +	0	0	0

PET-CT -	9	33	42
Total	9	33	42

Table 2. Paired Detection of Peritoneal Disease (reference = SL and cytology).

Overall, SL altered management in 18/42 (43%) patients. The main reasons were detection of peritoneal disease (9/42, 21.4%), positive cytology (4/42, 9.5%), or superficial liver metastases (2/42, 4.7%). In three cases, equivocal PET findings were clarified by SL, changing intent from curative to palliative (Table 3).

Reason for change	n/N	%
Peritoneal disease detected	9/42	21.4
Positive peritoneal cytology	4/42	9.5
Superficial liver metastases	2/42	4.7
Clarification of equivocal PET findings	3/42	7.1
Total management changes	18/42	42.9

Table 3. Management Changes after Staging Laparoscopy.

Discussion

Gastric cancer (GC) is an aggressive malignancy with a poor overall prognosis. Its management requires a multidisciplinary team, with treatment plans personalized based on tumor stage, therapeutic goals, and the patient's general health. Surgery and chemotherapy are the primary treatment modalities, but accurate staging is essential to guide effective management [4]. Both PET CT and staging laparoscopy play important roles in this process. PET-CT is a valuable, non-invasive modality for detecting distant metastases; however, its accuracy in assessing local tumor depth (T staging) is limited compared with endoscopic ultrasound (EUS) and staging laparoscopy (SL) [5]. In our study, PET-CT was able to demonstrate extra-serosal involvement in certain cases, but SL provided greater accuracy in evaluating local tumor spread, particularly in advanced disease. EUS generally remains the preferred modality for T staging, with reported accuracy rates between 65% and 92%. SL, especially when combined with laparoscopic ultrasound, can effectively distinguish between potentially resectable (T3) and unresectable (T4) tumors. Thus, while PET-CT is beneficial for non-invasive systemic evaluation, SL plays a critical role in determining operability, particularly in advanced-stage gastric cancer. In our cohort, 52.3% (n = 22) of patients were classified as cT3 on PET-CT. Among these, 4 patients (18%) were subsequently upstaged to cT4a on SL, a finding that had been missed on PET-CT. Histopathological analysis of these upstaged cases revealed that 3 patients (75%) had poorly differentiated adenocarcinoma with a signet-ring cell variant, and 1 patient (25%) had mucinous adenocarcinoma. Notably, PET-CT and SL findings were comparable for cT2 disease. These results suggest that from cT3 stage onward - particularly in patients with poorly differentiated or mucinous histologies - SL should be strongly recommended to avoid under-staging and ensure accurate assessment of operability. Accurate assessment of nodal status is essential for guiding both surgical and oncological management in gastric cancer. However, current literature indicates that conventional imaging modalities including AUS, EUS, MDCT, MRI, and PET are often inadequate for reliably detecting metastatic lymph nodes. The spatial resolution of FDG PET-CT may be insufficient to distinguish between the primary tumor and adjacent perigastric nodes, and nodal metastases are frequently present in subcentimeter nodes that do not meet CT size criteria. Although PET-CT can provide prognostic information, with FDG-avid nodes generally associated with poorer outcomes, its sensitivity and specificity remain limited. In our study, 88.1% (n = 37) of patients demonstrated significant SUVmax elevation in perigastric nodes on PET-CT, whereas only 19.1% (n = 8) had nodes visualized during staging laparoscopy. Importantly, PET-CT nodal uptake did not correlate with histopathological grade or tumor biology of the primary tumor [6]. Furthermore, the lack of histopathological validation or indocyanine green

(ICG) mapping in our cohort restricts definitive conclusions regarding nodal staging accuracy. These findings underscore the limitations of both PET-CT and staging laparoscopy for nodal evaluation. While PET- CT may serve as a marker of tumor aggressiveness, more accurate preoperative assessment of nodal status will likely require integration of novel techniques such as laparoscopic ultrasound or ICG fluorescence-guided imaging. Laparoscopy has been shown to be more effective than conventional preoperative imaging for detecting peritoneal carcinomatosis. While CT scans can identify peritoneal metastases with variable accuracy (30%–100%) and low sensitivity (as little as 28.8%), PET scans also demonstrate limited sensitivity, with detection rates of only 30%–35.3% [7-10]. According to the American Joint Committee on Cancer (AJCC) TNM 8th edition and international guidelines, positive peritoneal cytology is classified as metastatic disease; however, treatment protocols for patients with isolated positive cytology without gross peritoneal deposits remain poorly defined [11, 12]. In our study, staging laparoscopy identified peritoneal disease in 21.4% (n = 9) of patients, despite no evidence on PET/CT. Importantly, SL detected omental deposits in 14.2% (n = 6) and isolated omental lesions in 7.2% (n = 3) that had been missed by PET-CT. These findings underscore the incremental value of laparoscopy in identifying subtle peritoneal and omental metastases. Patients with peritoneal disease also frequently showed nodal uptake on PET, which was later confirmed intraoperative. However, the nodal findings in our study were not validated against surgical pathology, and thus interpretation of PET versus SL for nodal staging should be made cautiously. For liver metastasis, current guidelines recommend CT as the first-line imaging modality; however, its accuracy (60%–100%), sensitivity, and specificity (91.5%–100%) vary widely. While PET has been suggested as a superior option, this view is not universally supported. Meta-analyses indicate that diagnostic laparoscopy has a sensitivity ranging from 0% to 79%, reflecting its limitation in detecting deep parenchymal lesions, though it remains valuable for superficial deposits. In our series, staging laparoscopy revealed liver metastasis in 4.7% (n = 2) of patients who had been staged as M0 on PET/CT. One had peritoneal carcinomatosis with superficial hepatic deposits, while the other had isolated superficial lesions missed by PET-CT. This further highlights the complementary role of laparoscopy in metastatic assessment [13 ,14]. Histopathological correlation of the M1 cases detected exclusively on SL (n = 10; 23.8%) showed that 11.9% (n = 5) were poorly differentiated adenocarcinomas with signet-ring features, 9.5% (n = 4) were mucinous adenocarcinomas, and 2.3% (n = 1) was an undifferentiated type. These findings are consistent with Mukai K. et al. [10-23], who reported reduced sensitivity and specificity of PET in detecting metastases in such histological variants. Based on this, SL should be strongly recommended in cases with poorly differentiated or mucinous histology for accurate metastatic staging [11, 13, 14]. A key strength of staging laparoscopy is its direct impact on clinical decision-making. In our series, management was altered in 43% (n = 16) of patients following SL findings, with changes ranging from avoiding unnecessary laparotomy to redirecting treatment toward neo adjuvant chemotherapy or palliative care. This underscores the practical utility of SL in refining treatment strategies, particularly in settings where imaging alone may underestimate metastatic burden. These results are consistent with prior reports, though variation across studies reflects differences in patient selection, imaging protocols, and histologic subtypes.

Despite the progress in imaging modalities such as MDCT, MRI, and PET, our findings confirm the continued importance of staging laparoscopy in gastric cancer. In our series, 43% of patients experienced treatment modification following SL, consistent with published meta-analyses reporting management changes in a substantial proportion of cases [3, 13]. The limited sensitivity of modern imaging in detecting subtle or early peritoneal metastases remains a critical shortcoming, reinforcing the role of laparoscopy as an essential tool in ensuring accurate disease staging and optimizing treatment strategies.

Generalizability and Limitations

This was a single-center study from Odisha, India, where both PET-CT and SL are available. The cohort included a relatively high proportion of poorly differentiated tumors (signet ring and mucinous variants), which may limit applicability to populations with different histologic

distributions. Nodal findings could not be confirmed pathologically, restricting firm conclusions about accuracy. Finally, the sample size was modest, underscoring the need for validation in larger, multicenter cohorts. Multicentric large-scale prospective studies with a greater sample size must be undertaken in patients with gastric cancer in our country, the data on which is lacking, to assess the specificity and sensitivity of both the investigation modalities for treatment of gastric cancer. For lymph node examination via staging laparoscopy, ICG monitoring was not used. After D2 radical gastrectomy, also histopathological involvement of nodal status was not included in the study. Here we documented lymph nodal status as per laparoscopic observation only. All patients underwent staging laparoscopy after PET CT scan. In our study cohort, staging laparoscopy is done only after a nonmetastatic PET scan report.

In conclusion, our study emphasizes the continued importance of staging laparoscopy in the management of gastric cancer, despite advancements in preoperative imaging technologies. While PET CT and other imaging modalities provide valuable information, they often fall short in detecting peritoneal metastases. Staging laparoscopy significantly improves the accuracy of staging, particularly in identifying peritoneal disease and unresectable lesions, which can alter treatment plans and avoid unnecessary surgeries. In our study, 21.4% (n = 9) patients with peritoneal disease were detected only by staging laparoscopy, and in 4.7% (n = 2) patients were found to have distant visceral metastases that were missed in the PET CT scan. PET SCAN has superiority in detecting perigastric nodal status, which is lacking in conventional staging laparoscopy. PET SCAN is less sensitive with poorly differentiated signet ring variant and mucinous variant of adenocarcinoma of primary tumour, and in these cases staging laparoscopy is unavoidable. False negative finding of PET CT scan in detecting metastatic disease is approximately 23% in our study. So PET CT scans cannot replace staging laparoscopy for diagnosis and treatment plan for locally advanced gastric cancer. Despite ongoing challenges, PET and PET/CT imaging hold promise for standardizing and improving the accuracy of gastric cancer diagnosis and evaluation. Additionally, staging laparoscopy facilitates tissue sampling, intraoperative ultrasound, and therapeutic procedures. Form these findings suggest we must include staging laparoscopy in locally advanced gastric cancer staging guidelines in association with FDG PET CT scan.

Declarations Competing Interests

The authors declare that they have no competing interests.

Ethical Approval

The study was approved by the Institutional Ethics Committee of IMS & SUM Hospital, Bhubaneswar, Odisha.

Consent to Participate

Written informed consent was obtained from all participants prior to enrolment.

Consent for Publication

Not applicable.

Data Availability

Data sharing is not applicable to this article as no datasets were generated or analysed during the

current study.

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