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ORIGINAL RESEARCH

# Preoperative Staging of Gastric Cancer Using Computed Tomography and Its Correlation with Histopathology with Emphasis on Multi-planar Reformations and Virtual Gastroscopy

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## Abstract

**Background** Gastric cancer is the fifth most common cancer in the world. Preoperative staging of gastric cancer has assumed pivotal role in deciding appropriate management of gastric cancer with multi-detector computed tomography (MDCT) using hydro- and gaseous distension of stomach superseding endoscopic ultrasound in tumor (T) and nodal (N) staging. We undertook this study to evaluate the diagnostic accuracy of MDCT in the T and N staging of gastric cancer with an attempt to differentiate between early and advanced gastric carcinomas.

**Methods** A total of 160 patients with endoscopically diagnosed and biopsy-proven gastric cancer were subjected to MDCT after adequate gaseous and hydro-distention of stomach. Multi-planar reformatted (MPR) as well as virtual gastroscopy images were also obtained. Gastric lesions were categorized into T1 to T4 stages with N staging from N0 to N3. Preoperative CT findings were correlated with histopathological findings.

**Results** Overall diagnostic accuracy of T staging in our study was 82.5% (132/160) with an accuracy of 75% (120/160) for N staging. The diagnostic accuracy of CT for early gastric carcinoma in our study was 93.75% with high specificity of 96% but low sensitivity of 66.7%.

**Conclusion** MDCT using gaseous and hydro-distension of stomach is an excellent modality for near accurate preoperative T staging of gastric cancer. However, CT has a limited role in the N staging of gastric cancer. This study also suggested that the combined use of virtual gastroscopy and MPR images helps in better detection of early gastric cancers.

**Keywords** Multi-detector computed tomography · Early gastric cancer · Virtual gastroscopy · Advanced gastric cancer and hydro-distension

## Background

Gastric cancer is the fifth most common neoplasm and the third most deadly cancer, with an estimated 783,000 deaths in 2018 [1]. Its age-adjusted rate (AAR) among urban registries in India is 3.0–13.2 compared with the worldwide AAR of 4.1–95.5 [2–5]. Hospital-based cancer registry of Regional Cancer Centre of the state of Jammu and Kashmir, India, shows it to be the third most common cancer in both males and females in this part of India [6]. The 5-year survival rates range from 3% in case of stage IV to 85–90% in case of stage I disease [7, 8]. Preoperative staging of gastric cancer is vital to decide an appropriate treatment plan [9]. Prognosis is determined by the depth of invasion of the stomach wall and nodal involvement [10]. Accurate preoperative staging helps to increase cure rates and quality of life [11] because a small early gastric cancer limited to the submucosa (T1 stage) can be treated with endoscopic mucosal resection

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[12], whereas preoperative neoadjuvant therapy is recommended for advanced gastric cancer. Multi-detector computed tomography (MDCT) with hydro- and gaseous distension has superseded preoperative endoscopic ultrasound (EUS) in tumor (T) and nodal (N) staging [11] due to superior differentiation of tumor tissue from normal gastric mucosa. Isotropic MDCT imaging of the stomach using thin collimation enables high-quality multi-planar reformations (MPRs). Virtual gastroscopy images achieved by optimal gaseous distention of stomach help in evaluation of gastric endoluminal disease in early gastric cancer [8, 13]. In view of very high prevalence of gastric cancer in our valley and frequent under-staging of this cancer by various imaging modalities including computed tomography, this study was conducted to accurately stage gastric cancer and hence determine the operability.

## Methods

The present study was prospective, single center, and observational in the design, conducted between September 2015 and December 2017. Institutional Ethical Committee (IEC) approval was obtained for the study under no. SIMS 131/IEC-SKIMS/2015-83, and a signed consent form was obtained from each patient. A total number of 167 patients diagnosed with primary gastric carcinoma on biopsy obtained during esophagogastroduodenoscopy (EGD) underwent MDCT for staging purpose. All patients were subjected to surgical procedure within 30 days from the staging CT, in order to obtain a pathological staging comparable to the preoperative evaluation. Surgical procedure, when indicated, was performed on an average after 11 days from the CT.

### Inclusion Criteria

Patients diagnosed with gastric carcinoma on EGD and subsequently proved by biopsy were included in the study.

### Exclusion Criteria

Patients with liver metastasis, peritoneal carcinomatosis, pancreatic invasion with retroperitoneal lymphadenopathy, gastroesophageal (GE) junction tumors, hypersensitivity reaction to intravenous contrast, and severely deranged renal function were excluded from the study.

### Patient Preparation and Imaging Protocol

After overnight fasting, patients were given 4 to 7 g of gas-producing powder (trade name Eno) orally mixed with a few milliliters of water shortly before the start of unenhanced CT to attain optimal gastric distension. Preliminary topogram was obtained to determine the area of abdomen to be scanned on non-contract CT. Unenhanced scan was performed cranially from just above the domes of diaphragm to just below the inferior margin of the air-distended stomach caudally. Scanning was performed using mAs of 250–300, kVp of 120, and a collimation of 1.25 mm. After unenhanced scan, each patient drank 0.5–1 L of water. Of a non-ionic iodinated contrast agent (Omnipaque), 100–150 ml (depending on patient's body weight) was administered via the antecubital vein at 4–5 ml/s by using an 18-gauge cannula and an automatic injector. CT was performed in the late arterial phase (35–45 s after start of contrast injection), in the portal venous phase (60–80 s), and in the delayed phase (160–180 s). The late arterial and delayed phases were used to evaluate T stage; the portal venous phase was used to evaluate N stage. Reconstruction was done using section thickness of 1.5 mm with reconstruction interval of 1 mm. Virtual gastroscopy was performed using the fly-through intraluminal navigation technique provided on Siemens workstation. Patients who on preliminary assessment on CT MPR images showed transmural gastric wall involvement or extraserosal growth were not subjected to virtual gastroscopy examination of stomach. Patients who on MPR CT images showed features of early gastric cancer (EGC) were subjected to the virtual gastroscopy of the stomach.

### Image Interpretation

Experienced radiologist with 15 years of experience in gastrointestinal radiology blinded to the endoscopic results preoperatively analyzed these cases on Siemens CT work station. Morphological assessment of the lesion in each patient was performed to determine the location and gross appearance of the tumor. Gross appearance of tumor was classified either as polypoid, fungating, ulcerated, or diffusely infiltrative. Degree of enhancement was graded as high, moderate, or low [14]. Gastric wall infiltration (T) was evaluated, in accordance with the AJCC 7th edition with reference to the "New MDCT Criteria" by Kim et al. [15] (T1a—tumor showed enhancement and/or thickening of the abnormal mucosa, as compared with the adjacent normal mucosa, with an intact low-density—stripe; T1b—disruption of the low-density-stripe (less than 50% of the thickness); T2—disruption of the low-density-stripe (greater than 50% of the thickness) without abutting on the outer high-attenuating layer; T3—discrimination between the enhancing gastric lesion and the outer layer was indiscernible, and a smooth outer margin of the outer layer or a few small linear strandings in the perigastric fat plane were visualized; T4a—an irregular or nodular outer margin of the outer layer and/or a dense band-like perigastric fat infiltration was visualized; and T4b—obliteration of the fat plane between the gastric lesion and the adjacent organs or direct invasion of the adjacent organs). Criteria for significant nodes were short-axis diameter of ≥ 8 mm, round or irregular shape with or without fatty hilum, and post contrast enhancement (defined as attenuation > 85 HU in the portal venous phase). Node(s) with surrounding reticular strands independent of size and enhancement pattern were also

taken as significant [13]. Preoperative CT staging of both the primary gastric T and N stages was noted down. The preoperative CT staging was then compared with the surgical and HPE findings to determine the accuracy of T and N stages of the tumor.

### Statistical Analysis

The results were compiled and analyzed using standard statistical methods in order to find the accuracy of CT imaging in staging of gastric cancer. Continuous variables were expressed as mean, median, and standard deviation. Statistical analysis was performed on collected data calculating accuracy, sensitivity, specificity, positive and negative predictive values, and their 95% confidence interval for each T and N stage and overall staging. The level of agreement between CT and pathological staging was measured with Cohen's kappa test for T and N stages and overall staging. The $p$ value of $< 0.01$ was considered statistically significant. The agreement between CT and HPE was evaluated with the Kappa method, according to Landis and Koch ($\leq 0$: poor agreement; 0.01–0.20: slight agreement; 0.21–0.40: fair agreement; 0.41–0.60: moderate agreement; 0.61–0.80: substantial agreement; 0.81–1.0: almost perfect agreement). Results were obtained with the help of MS Excel and SSPS software.

## Results

Out of the total 167 patients who had detectable lesion on MDCT, 132 were males and 35 were females with a male to female ratio of 3.7:1 and mean age of 62.21 years (range 40–85). All 167 patients underwent surgical procedures which included total gastrectomy in 69 patients and subtotal gastrectomy in 91 patients. Seven patients in whom CT showed definite pancreatic invasion underwent diagnostic laparoscopy, which also confirmed infiltration of gastric tumor into the pancreas, and were excluded from statistical analysis. Out of 160 operated patients 50 underwent D1 lymphadenectomy (removal of station 1 to station 7 nodes) and 110 had D2 (removal of station 1 to 12a nodes) lymphadenectomy. The distribution of various tumor characteristics on CT like tumor location, morphology of growth, wall thickness at the site of tumor, and degree of enhancement is shown in Table 1. Three patients did not reveal any obvious or overt gastric thickening on multi-planar reformatted images. On virtual CT gastrography, these patients showed mucosal irregularities. The mean thickness of tumor was 19.9 mm (range 7–40 mm). The mean thickness in early gastric cancer was 10.14 mm with SD ± 3.29 and 20.84 mm in advanced gastric cancer with SD ±7.26 ($p$ value $< 0.05$). Distribution of features of partial or total mural extension like less than or more than 50% disruption of low-density outer stripe layer, character of outer serosal margin, perigastric fat infiltration, and plane with adjacent organs/invasion is also summarized in Table 1. Fourteen patients who showed preserved outer low-density stripe or less than 50% disruption of outer low-density stripe on preoperative CT were staged as T1 disease (Fig. 1). Twelve patients who showed greater than 50% disruption of outer low-density stripe on preoperative CT were classified as T2 disease (Fig. 2). Forty-four patients showed complete disruption of outer low-density stripe but with smooth outer margin or few strands in perigastric fat and were assigned CT stage of T3 (Fig. 3). Seventy patients showing irregular, nodular outer gastric margin with dense bands in perigastric fat were classified as T4a (Fig. 4). Six patients who were staged as T3 on CT proved to be T4a on HPE (Fig. 5). Twenty patients who showed obliteration of perigastric fat plane or frank invasion into surrounding organs were classified as T4b (Fig. 6). Relative percentages of various T stages on CT and comparison of CT T stage and T staging by HPE are given in Table 2. Histopathologically proven T4b patients showed infiltration into left lobe of the liver ($n = 4$), transverse mesocolon ($n = 8$), transverse colon/splenic flexure ($n = 4$) (Fig. 6a, b), and spleen ($n = 2$). These patients underwent extensive surgical resection with removal of both the stomach and the surrounded infiltrated organ. Those patients who showed obliteration of fat plane with pancreas on CT obtained in supine position (Fig. 6c) were subjected to a repeat scan in the prone position to demonstrate adherence of the growth with the pancreas (Fig. 6d). Forty-two patients were staged as N0, 42 patients as N1, 44 patients as N2, and 32 patients as N3 (Fig. 7). Twenty patients were understaged, and further, 20 patients were over-staged on preoperative CT. Table 3 shows the comparison of N staging on CT and HPE. The sensitivity, positive predictive value (PPV), negative predictive value (NPV), and agreement of CT with HPE (Cohen's Kappa) are given in Table 4.

## Discussion

Preoperative staging of gastric cancers assumes central role in chalking out a comprehensive treatment plan for gastric cancer patients. With the growing interest towards a more conservative treatment approach for early gastric cancers and greater evidence of benefit of neoadjuvant/perioperative chemotherapeutic strategy for advanced stages, preoperative staging has become a sine qua non in order to exclude nodal involvement and infiltration beyond the submucosa. Staging also helps to get a baseline reference point to evaluate response to preoperative treatment. MDCT with stomach protocol of using stomach distension with neutral (water) or negative (air) media makes it a preoperative non-invasive staging technique with high accuracy, repeatability, and non-operator dependency. Preoperative CT staging now contributes significantly to the therapeutic decision-making process. CT has a high accuracy in detecting location of gastric tumor and its various morphological characteristics. Primary tumor was detected in 157 patients on CT in our study (98.1% detection rate) using only MPR images. MDCT, with thin

**Table 1** Various gastric tumor characteristics on MDCT

| S. no. | | | | | |
|---|---|---|---|---|---|
| 1. | Tumor location ($N = 160$) | Antropyloric region | Corpus | Cardia | Diffuse thickening |
| | | $n = 100$ (62.5%) | $n = 36$ (22.5%) | $n = 20$ (12.5%) | $n = 4$ (2.5%) |
| 2. | Morphology of growth ($N = 160$) | Fungating | Polypoid | Ulcerated | Diffuse infiltrative |
| | | $n = 98$ (61.3%) | $n = 50$ (31.2%) | $n = 8$ (5%) | $n = 4$ (2.5%) |
| 3. | Wall thickness at the site of tumor ($N = 160$) | < 10 mm | 11–20 mm | 21–30 mm | 31–40 mm |
| | | $n = 8$ (5%) | $n = 88$ (55%) | $n = 46$ (28.8%) | $n = 18$ (11.2%) |
| 4. | Degree of enhancement ($N = 160$) | High | Moderate | Low | |
| | | $n = 134$ (83.8%) | $n = 8$ (5%) | $n = 18$ (11.2%) | |
| 5. | Low-density outer stripe layer ($N = 160$) | < 50% disruption | > 50% disruption but present | Absent | |
| | | $n = 14$ (8.7%) | $n = 12$ (7.5%) | $n = 134$ (83.8%) | |
| 6. | Outer serosal margin ($N = 160$) | Smooth | Nodular or irregular | | |
| | | $n = 70$ (43.8%) | $n = 90$ (56.2%) | | |
| 7. | Perigastric fat infiltration ($N = 160$) | Absent | Few linear strands | Dense infiltration | Absent or few linear strands but nodular or irregular outer margin |
| | | $n = 44$ (27.5%) | $n = 26$ (16.2%) | $n = 70$ (43.8%) | $n = 20$ (12.5%) |
| 8. | Plane with adjacent organs/invasion ($N = 160$) | Maintained | Not maintained | Frank invasion | |
| | | $n = 140$ (87.5%) | $n = 14$ (8.7%) | $n = 6$ (3.8%) | |

collimation allowing near-isotropic imaging, offers high-quality MPRs. MPR images are important in the assessment of primary gastric tumor as stomach is oriented obliquely, and multi-planar evaluation of gastric tumors helps in detailed assessment. MPRs also have the advantage of assessing both intra- and extraluminal processes of the gastric wall. Combined transverse and MPR images increase the diagnostic accuracy by showing the tumor and perigastric fat in profile, allowing better evaluation of tumor invasion. We performed endoluminal three-dimensional virtual gastroscopy in only EGCs (fourteen patients in our study

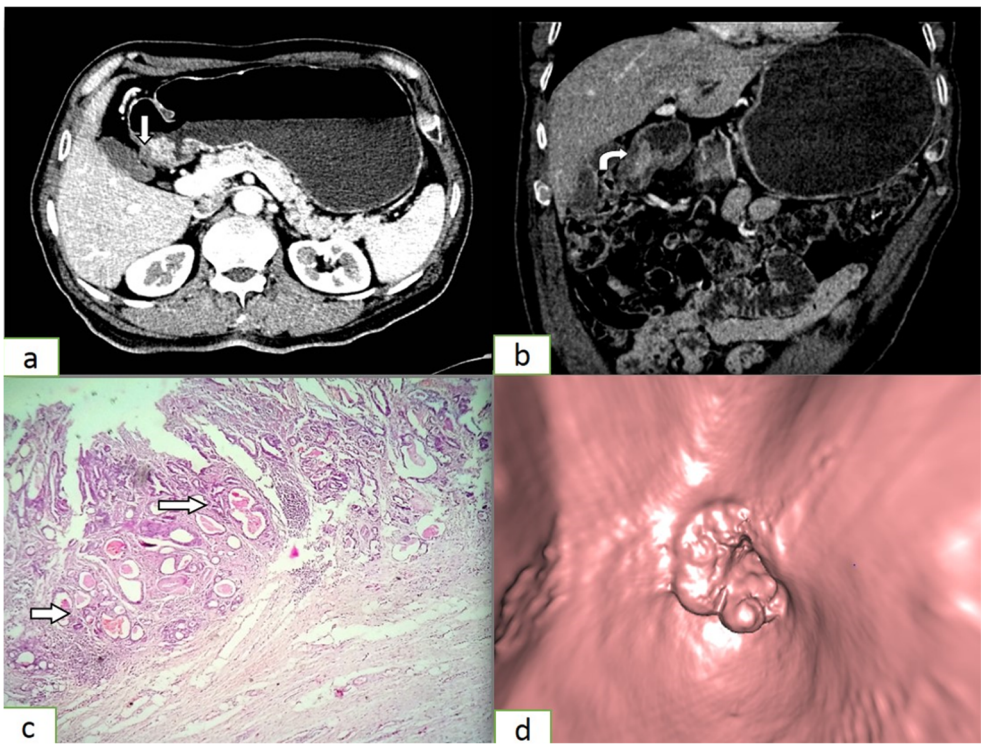


**Fig. 1** Transverse (**a**) and oblique coronal MPR (**b**) contrast-enhanced CT images of 60-year-old patient showing polypoidal enhanced mucosal thickening (straight arrow) of the pyloric region with hypoattenuating outer stripe layer (curved arrow) seen surrounding the tumor suggesting stage T1. Histopathology confirmed stage T1 as shown in photomicrograph (**c**) with tumor tissue arranged in irregular glands with central lumen containing necrotic debris (arrows). The tumor is limited to mucosa (scanner view 4×). Virtual gastroscopy image (enface) of the same patient showing a polypoidal tumor in the pyloric region with smooth border (**d**)

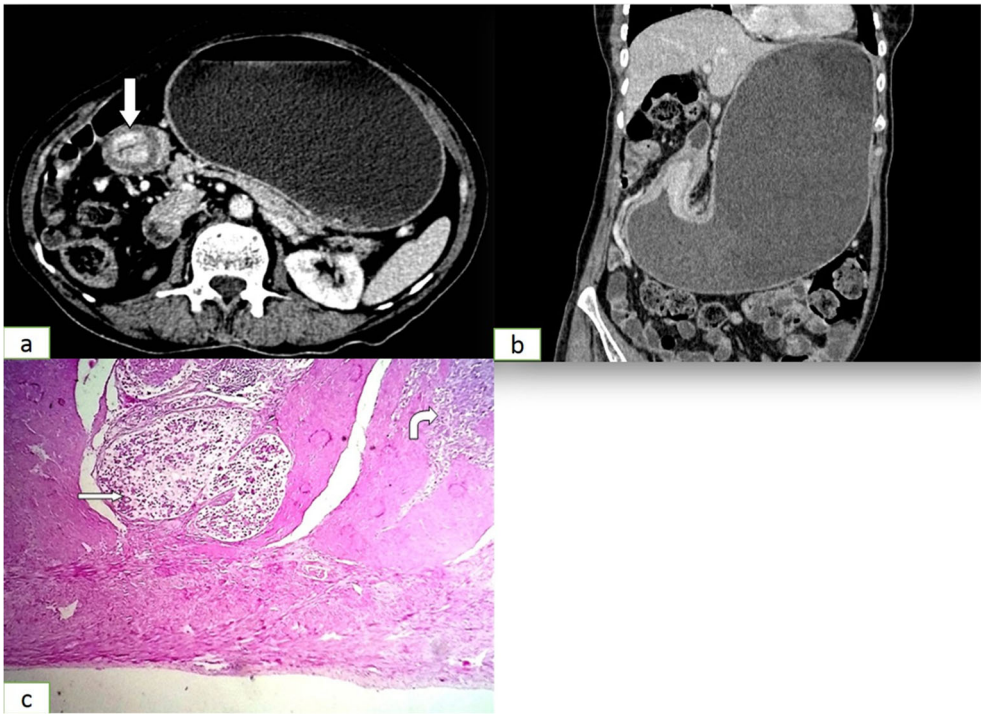


**Fig. 2** Transverse (**a**) and coronal MPR (**b**) contrast-enhanced (portal venous phase) CT images of 66-year-old female patient showing circumferential enhancement and thickening of antrum. Note low attenuation outer stripe layer (arrow) with more than 50% disruption representing submucosal-muscular layer with partial infiltration. This finding is suggestive of stage T2. Histopathology confirmed stage T2 as shown in photomicrograph (**c**) with tumor arranged diffusely in sheets infiltrating into muscularis propria (arrow). Note that the tumor has generated lymphoid response (curved arrow) (scanner view 4×)

(8.8%)). Three lesions not detected by using only MPR images were detected as subtle mucosal irregularities on virtual gastroscopy which on subsequent postoperative HPE proved to be EGCs (shallow ulcerative lesions). This underlines the value of routine use of virtual gastroscopy in early gastric cancers as we detected three additional lesions in 14 cases which were not detected using MPR images alone. Our findings are in agreement with the Chen et al. [13] who in their study had concluded that combined virtual gastroscopy and dynamic contrast-enhanced MPRs is a superior technique in picking early gastric cancer owing to its ability to reveal subtle mucosal changes. Virtual gastroscopy facilitates evaluation of internal surfaces of stomach,

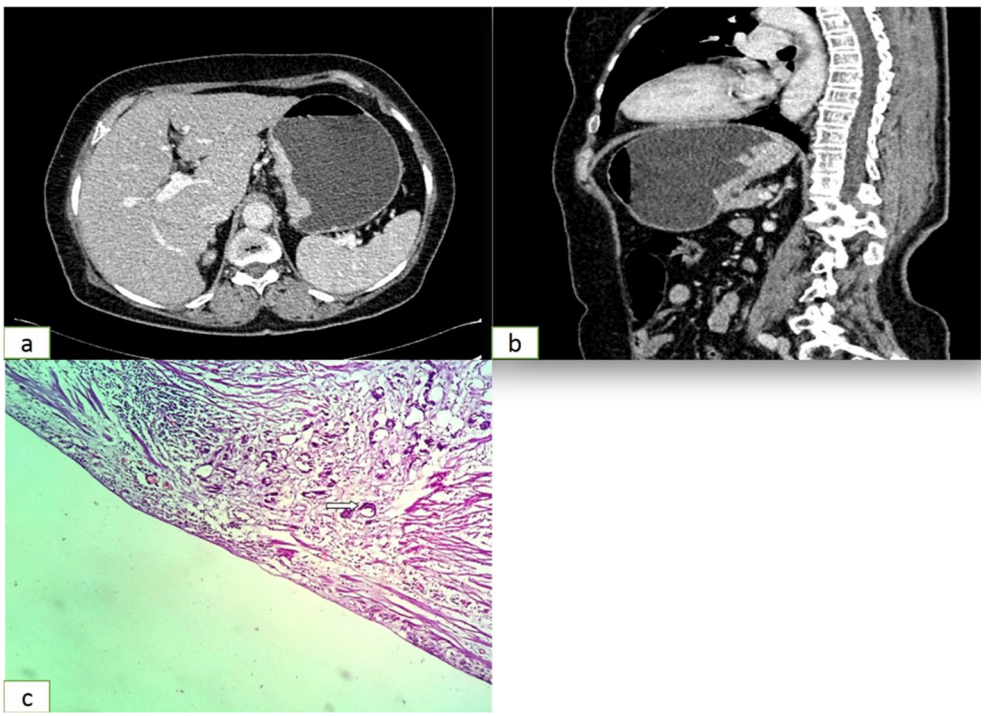


**Fig. 3** Transverse (**a**) and sagittal MPR (**b**) portal venous phase CT images showing transmural enhancing thickening along lesser curvature of the body of stomach with smooth outer border. This finding is suggestive of stage T3 on CT. Histopathology confirmed stage T3 as shown in photomicrograph (**c**) with tumor arranged diffusely and in small glands infiltrating up to serosa but not breaching serosa (arrow). Lymphoid inflammatory infiltrate is also seen in the field (scanner 4×)

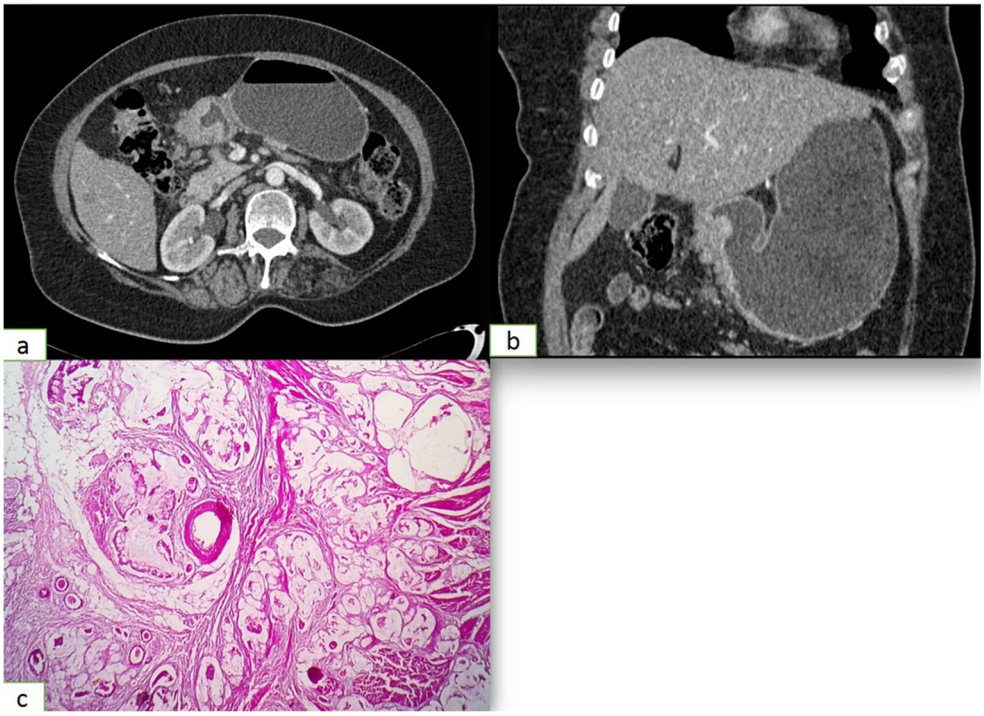


**Fig. 4** Transverse (**a**) CT image showing transmural enhanced thickening involving antrum with a small hypodense lesion in segment VI of liver which was found to be anechoic on ultrasound. Oblique coronal MPR (**b**) image in the same patient shows enhanced transmural thickening. Nodular outer serosal margin and perigastric fat infiltration are seen better on coronal MPR suggesting stage T4a. Histopathology confirmed stage T4a as shown in photomicrograph (**c**) with tumor arranged in small glands breaching serosa, and there are abundant mucin pools. Vessel is also seen in the center of the field (scanner 4×)

thereby allowing increased detection of shallow ulcerative lesions (EGCs). Virtual gastroscopy images usually exceed the temporal limits of optical EGD in the evaluation of lesser curvature and allow even retrospective evaluation of missed spots. Virtual gastroscopy without MPR images, however, allows neither evaluation of trans/perigastric tumor invasion nor nodal/distant metastasis. Other shortcomings of virtual gastroscopy include its dependency on specific stomach protocol, food residue adherent to gastric mucosa mimicking a lesion, radiologist requirement, and increased examination time per patient [16].

The most common site of tumor in our study was antropyloric region followed by body, cardia, and diffuse involvement. The reason for the antropyloric region being the most common location in our study population was the exclusion of GE junction tumors from our study. Tumors involving GE junction which arise from lower esophagus or within

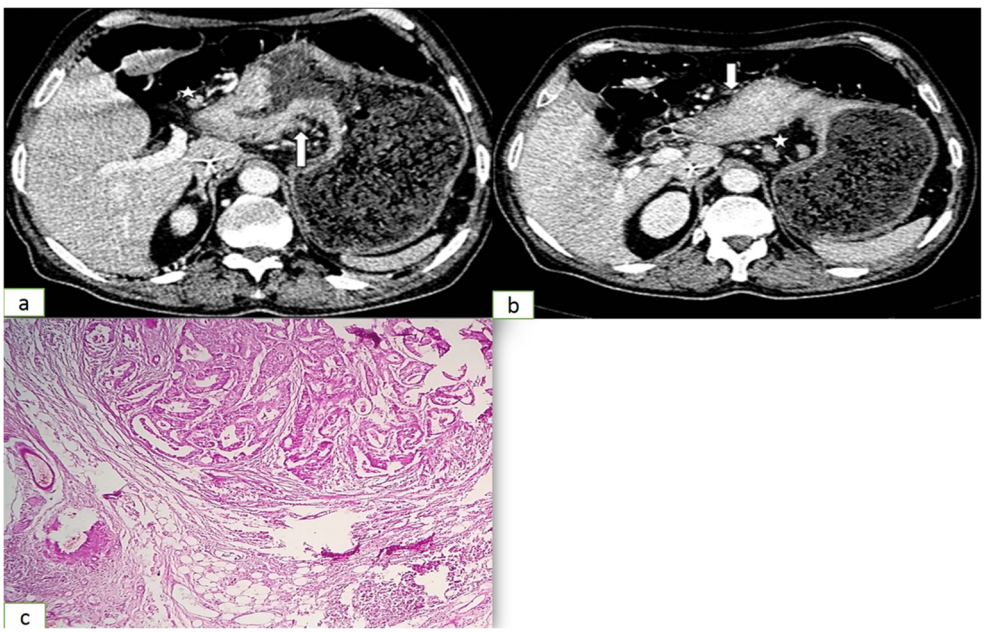


**Fig. 5** Transverse contrast-enhanced CT images (**a**, **b**) in a 59-year-old patient showing transmural enhanced thickening with nearly smooth outer border and few linear perigastric strands (arrows). Note the presence of some enlarged perigastric nodes (star). These features are suggestive of stage T3. **c** Photomicrograph of same patient with tumor tissue arranged in glands, breaching serosa and extending into the surrounding fat. Features were suggestive of well differentiated adenocarcinoma (stage T4a)

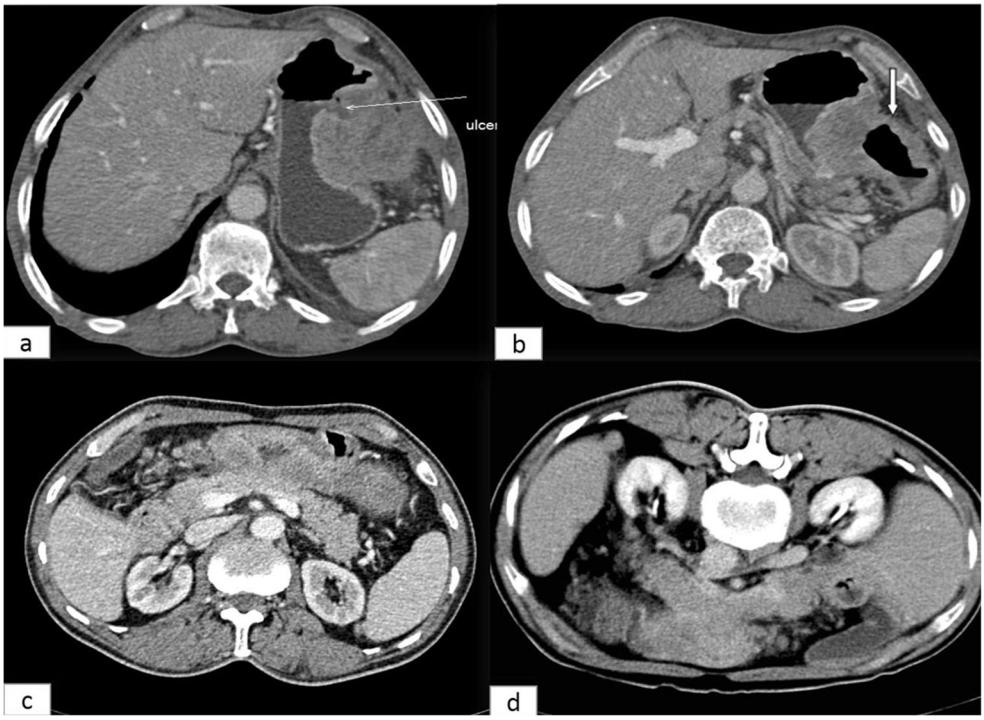


**Fig. 6** Transverse (**a**) contrast-enhanced CT image in a 66-year-old patient showing large fungating growth with a central ulcer. Section below (**b**) shows growth infiltrating the splenic flexure of colon with loss of intervening fat plane (arrow) suggesting stage T4b.Transverse (**c**) contrast-enhanced CT image in supine position shows circumferential transmural thickening with obliteration of fat plane with pancreas. Transverse (**d**) contrast-enhanced CT image in the prone position confirming infiltration of growth into pancreas, thereby suggesting stage T4b. Histopathology showed tumor cells mostly dispersed individually and in sheets along with few cells arranged in glands (poorly differentiated adenocarcinoma) infiltrating into pancreatic parenchyma

proximal 5 cm of stomach and cross GE junction are staged and treated as esophageal cancers, whereas tumors arising within proximal 5 cm of stomach but not crossing GE junction are classified as gastric cancers [17, 18]. Statistically significant difference ($p$ value < 0.001) was found in the mean thickness of primary tumor between early and advanced gastric cancers. Owing to their hypervascularity (neovascularity) on dynamic contrast-enhanced CT images, most gastric cancers are seen as enhancing lesions [19, 20]. Eighteen tumors (11.3%) in our study showed low enhancement, all of which subsequently proved to be of signet ring/mucinous morphology on HPE. Our findings are in agreement with the study conducted by Chen et al. [13] and Park et al. [14]. Lee et al. [17] retrospectively reviewed MDCT results in 80 patients with pathologically proven advanced gastric carcinoma with signet ring cell carcinoma ($n = 35$ patients) and non-signet ring cell carcinoma ($n = 45$ patients). In contradiction to our study, they reported high degree of contrast enhancement in signet ring cell carcinoma (37.1% of patients) than non-signet ring cell carcinoma (15.6% of patients) with statistically significant difference ($p < 0.001$).

**Table 2** Comparison of CT tumor stage and histopathology tumor stage

| CT T-stage | | Histopathological T-stage | | | | | |
|---|---|---|---|---|---|---|---|
| | | T1 | T2 | T3 | T4 | | Total |
| | | | | | T4a | T4b | |
| T1 | | 8 | 6 | 0 | 0 | 0 | 14 (8.8%) |
| T2 | | 4 | 8 | 0 | 0 | 0 | 12 (7.5%) |
| T3 | | 0 | 2 | 36 | 6 | 0 | 44 (27.5%) |
| T4 | T4a | 0 | 0 | 6 | 62 | 2 | 70 (43.7%) |
| | T4b | 0 | 0 | 0 | 2 | 18 | 20 (12.5%) |
| Total | | 12 | 16 | 42 | 70 | 20 | 160 |

The preoperative MDCT diagnostic accuracy was 93.7%, 92.5%, 91.2%, 90%, and 97.5% for T1, T2, T3, T4a, and T4b respectively with combined diagnostic accuracy of 92.5% of CT in diagnosing T4 lesions. The overall diagnostic accuracy of T staging in our study was 82.5% (132 out of 160 patients were diagnosed accurately) when T4a and T4b were taken as one group. If T1 and T2 are taken as a single group, then diagnostic accuracy increases and approaches to 100%. Fourteen patients were diagnosed as early gastric carcinoma (T1 stage) on CT; 146 of the patients were diagnosed as advanced gastric carcinoma (T2, T3, and T4 stages). The diagnostic accuracy of CT for early gastric carcinoma in our study was 93.7% with high specificity of 96% but low sensitivity of 66.7%. In our study, the sensitivity for diagnosis of T1/T2 lesions was low, equal to 66.7% for T1 and 50% for T2 lesions; it was higher for T3, T4a, and T4b lesions, equal to 85.7%, 88.6%, and 90%, respectively. As per the College of Oncology, National clinical practice guidelines, Gastric Cancer Version 2.2012, CT has low sensitivity for the diagnosis of T1–2 tumors and a moderate sensitivity for higher T-stages [21].

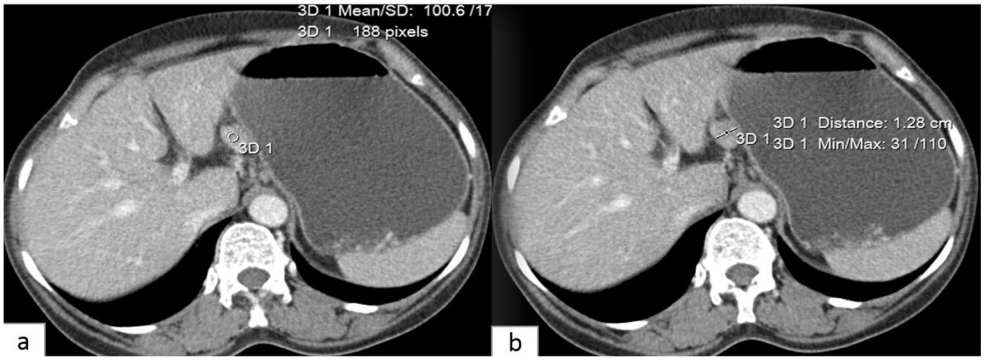


**Fig. 7** Transverse contrast-enhanced CT images showing enlarged (short-axis diameter of 12 mm) node (**a**) with degree of enhancement more than 85 HU (**b**). Subsequently, histopathology confirmed metastatic deposits within the node

Low-density outer stripe layer is present in T1 and T2 lesions with evidence of less than 50% disruption of this layer in T1 lesions and more than 50% disruption of this layer in T2 lesions. This low-density outer stripe is altogether absent in T3 and T4 lesions [15, 22]. However, interpretation of less than or more than 50% disruption of low-density outer stripe is subjective and may lead to over or under-staging of T1/T2 lesions. Moreover, this finding is dependent on the fact whether the stomach has single layered or multi-layered pattern on MDCT. Serosal margins are usually smooth in T1, T2, and T3 lesions and nodular/irregular in T4 lesions [15, 22]. Dense perilesional fat stranding signifying perigastric fat infiltration is usually seen in T4 lesions and is usually absent in T3 lesions, or a few linear strands may be present [15, 22]. Nodular outer margin and dense bands in the perigastric fat adjacent to the tumor usually represents extraserosal tumor extension (category T4a) but occasionally can be a result of reactionary inflammatory change, thus leading to false positive results when interpreted as tumor extension [23]. Kim et al. [24] concluded in their study that nodular or irregular outer margin with perigastric fat stranding were strong pointers in differentiating between T4a and less advanced gastric cancers.

The diagnostic accuracy of CT in diagnosing nodal stage was 87.5%, 78.8%, 87.5%, and 96.2% for N0, N1, N2, and N3, respectively. The overall diagnostic accuracy for N staging was 75% (120/160 patients identified correctly). It was comparable to study done by Chen et al. [13] who reported an accuracy of 78%. We under-staged 20 (12.5%) patients and over-staged 20 (12.5%) patients; it was comparable to Chen et al. [13] who under-staged 5 (9%) patients and over-staged 7 (13%) patients. Out of 38 patients without nodal involvement (N0 stage), 30 (83.33%) patients received correct classification, and in patients with nodal involvement (N1–N3), 90/132 (73.77%) patients received correct classification. The reported accuracy of CT diagnosis is 51–70% only because size is the only criterion used, and it is the poor indicator of involvement [10, 25, 26]. CT evaluation of nodal involvement is challenging with many limitations. CT has limited value in differentiating between neoplastic nodes with normal size (false negatives) and larger inflammatory nodes (false positives). This is the reason for over-staging and under-staging of nodal stages. In order to reduce the number of false positives, enhancement values of lymph nodes could be also considered. Metastatic lymph nodes are often characterized by different enhancement values as compared with normal nodes. Nodal involvement is also difficult to interpret in fat poor subjects and in patients with bulky stomach growth where the nodes are adherent to the stomach wall [27].

**Table 3** Comparison of nodal stage on CT and histopathology

| CT N-stage | Histopathological N-Stage | | | | |
|---|---|---|---|---|---|
| | N0 | N1 | N2 | N3 | Total |
| N0 | 30 | 12 | 0 | 0 | 42 |
| N1 | 8 | 28 | 6 | 0 | 42 |
| N2 | 0 | 8 | 34 | 2 | 44 |
| N3 | 0 | 0 | 4 | 28 | 32 |
| Total | 38 | 48 | 44 | 30 | 160 |

**Table 4** Statistical parameters

| Tumor/nodal stage | Sensitivity (%) | PPV (%) | NPV (%) | Cohen's kappa ( ) | Agreement with histopathology |
|---|---|---|---|---|---|
| T1 | 66.67 | 57.14 | 97.26 | 0.5816 | Moderate |
| T2 | 50.00 | 66.67 | 94.59 | 0.5313 | Moderate |
| T3 | 85.71 | 81.82 | 94.83 | 0.7774 | Substantial |
| T4a | 88.57 | 88.57 | 91.11 | 0.7968 | Substantial |
| T4b | 90.00 | 90.00 | 98.57 | 0.8857 | Almost perfect |
| T4 (T4a and T4b) | 93.33 | 93.33 | 91.43 | 0.8476 | Almost perfect |
| N0 | 78.95 | 71.43 | 93.22 | 0.6669 | Substantial |
| N1 | 58.33 | 66.67 | 83.05 | 0.4753 | Moderate |
| N2 | 77.27 | 77.27 | 91.38 | 0.6865 | Substantial |
| N3 | 93.33 | 87.50 | 98.44 | 0.8800 | Almost perfect |

Unfortunately, most of the cases diagnosed in our study were advanced gastric cancers. Due to lack of screening programs, most of the gastric cancer patients in our part of the world report late as early gastric cancers are usually asymptomatic. This is a limitation of our study as the number of early gastric cancers is small. However, 3 cases out of total of 14 T1 cases which were undetectable on MPR images were picked by virtual gastroscopy. Based on this small data, we cannot extrapolate these results to propose that CT gastroscopy is statistically superior in detection of early gastric cancers but we can suggest that large volume studies with large number of early gastric cancers would further demonstrate the exact role and utility of CT virtual gastroscopy.

## Conclusion

Our study suggests that MDCT using gaseous and hydrodistension of stomach is an excellent modality for near accurate preoperative tumor staging of gastric cancer, thereby helping in determining its operability. The addition of CT virtual gastroscopy to multi-planar reformations helps in detection of early gastric cancers. CT has limited role in nodal staging of gastric cancer.

**Authors' Contributions** WA analyzed and interpreted the computed tomography (CT) images. PA and NC also helped in interpretation and analysis of CT images. FI performed the histopathological examination of surgical specimen. FI was also involved in obtaining surgical specimen. All authors were involved in statistical analysis and data interpretation. All authors were also involved in manuscript preparation and literature research. All the authors have read and approved the manuscript.

**Data Availability** All the data and material were obtained from patients registered in our hospital.

### Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

**Ethics Approval** This observational study was duly approved by the Institutional Ethical Committee (IEC) of Sher-i-Kashmir Institute of Medical Sciences (SKIMS) under the no. SIMS 131/IEC-SKIMS/2015-83. No animal participants were used in this study.

**Consent to Participate** Informed verbal consent was obtained from all the patients included in the study.

**Abbreviations** AJCC, American Joint Committee on Cancer; AAR, age-adjusted rate; EGC, early gastric cancer; EGD, esophagogastroduodenoscopy; EUS, endoscopic ultrasound; GI, gastrointestinal; IEC, Institutional Ethical Committee; MDCT, multi-detector computed tomography; MPR, multi-planar reformation; MS, Microsoft; NPV, negative predictive value; N, nodal; PPV, positive predictive value; SSPS, Statistical Package for the Social Sciences; T, tumor

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