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FULL PAPER

MDCT features in the differentiation of T4a gastric cancer from less-advanced gastric cancer: significance of the hyperattenuating serosa sign

¹T U KIM, MD, ²S KIM, MD, ¹J W LEE, MD, ²N K LEE, MD, ³T Y JEON, MD and ⁴D Y PARK, MD

¹Department of Radiology, Pusan National University Yangsan Hospital, Pusan National University School of Medicine, Yangsan, Republic of Korea

²Department of Radiology, Biomedical Research Institute, Pusan National University Hospital, Pusan National University School of Medicine, Seo-Gu, Busan, Republic of Korea

³Department of Surgery, Biomedical Research Institute, Pusan National University Hospital, Pusan National University School of Medicine, Seo-Gu, Busan, Republic of Korea

⁴Department of Pathology, Biomedical Research Institute, Pusan National University Hospital, Pusan National University School of Medicine, Seo-Gu, Busan, Republic of Korea

Address correspondence to: Dr Suk Kim

E-mail: kimsuk@medimail.co.kr

Objective: The purpose of our study was to evaluate CT findings to differentiate between T4a and less advanced gastric cancers.

Methods: The institutional review board approved this study and waived informed consent. This study included 228 retrospectively identified patients with surgically confirmed gastric cancer (138 T1, 25 T2, 24 T3 and 41 T4a) and who had also undergone pre-operative CT scan. Transverse and multiplanar reconstruction scans were reviewed in consensus by two other blinded radiologists. The following CT findings that differentiate T4a from less advanced cancers were evaluated: nodular or an irregular outer layer of the gastric wall, haziness of the perigastric fat and a hyperattenuating serosa sign. The CT features of T4a and less advanced gastric cancers were compared by means of univariate and multivariate analyses.

Results: In univariate analysis, nodular or an irregular outer layer of the gastric wall, haziness of the perigastric fat and the hyperattenuating serosa sign were significant in differentiation between T4a and less advanced gastric cancers. In addition, nodular or an irregular outer layer of the gastric wall and the hyperattenuating serosa sign were significant in differentiation between T3 and T4a. In multivariate logistic analysis, the hyperattenuating serosa sign was the most significant finding in differentiation between T3 and T4a (odds ratio, 4.210; 95% confidence intervals, 1.581–11.214; $p=0.004$).

Conclusion: The hyperattenuating serosa sign may be a useful CT finding in differentiation between T4a and less-advanced gastric cancers.

Advances in knowledge: The hyperattenuating serosa sign is associated with gastric cancer with invading the serosa and can facilitate planning of the optimal pre-operative evaluation and treatment.

Gastric cancer is an important cause of death worldwide, as the fourth most common cancer and second leading cause of cancer-related deaths [1]. Gastric cancer is particularly common in eastern Asia.

The important prognostic factors of gastric cancer are the degree of tumour invasion and the presence of lymph node metastasis [2,3]. Despite relatively successful results of surgery in patients with gastric cancer, a poor prognosis is still associated with advanced gastric cancer, especially locally advanced cancer that invades the serosa and is classified as T4a in the TNM system [4,5]. Therefore, for locally advanced gastric cancer with serosal invasion, neoadjuvant chemotherapy is being used more frequently to downstage the tumour and treat micrometastases [6,7].

Endoscopic ultrasonography is considered the most effective diagnostic modality for evaluating the severity of gastric cancer, but it is invasive, operator-dependent and has a limited field of view.

Recent developments in multidetector CT (MDCT) have enabled thinner section collimation, faster scanning, optimal contrast enhancement and multiplanar reformation (MPR) for more accurate gastric cancer staging. Recently, some studies have demonstrated that MDCT with MPR and three-dimensional images can increase the accuracy of T staging in patients with gastric cancer [8,9].

In the recently released seventh TNM staging system of the American Joint Committee on Cancer/International

Union Against Cancer (AJCC/UICC), the T categories for gastric cancer have been modified as follows. T1 tumours have been divided into T1a (lamina propria or muscularis mucosae) and T1b (submucosa), T2 is defined as a tumour invading the muscularis propria, T3 is defined as a tumour invading the subserosal connective tissues and T4 is defined as a tumour invading the serosa (T4a) or adjacent structures (T4b).

For T4a gastric cancer staging, the reported CT accuracy varies considerably, ranging from 77.8% to 93.5% [9–12]. The reported CT criteria for T4a gastric cancer are nodular or irregular outer layer of the gastric wall and haziness of the perigastric fat. These widely used criteria may lead to overstaging of gastric cancer owing to peritumoural inflammation and serosal compression by the tumour [12,13].

We have encountered patients with pathologically assessed T4a gastric cancer in whom CT revealed a focal or diffuse thickened hyperattenuating outer layer of the gastric wall similar to the malignant target sign. The malignant target sign has been described as a feature of scirrhous metastases to the gastrointestinal tract by Gollub et al [14]. We hypothesised that the hyperattenuating outer layer of the gastric wall may be associated with gastric cancer of the serosa. We refer to this radiological finding as a hyperattenuating serosa sign. Therefore, the purpose of this study was to compare the ability of this sign to distinguish T4a gastric cancer from less severe grades with other radiological features.

MATERIALS AND METHODS

Patient selection

This retrospective study was approved by the institutional review board of our hospital, and the requirement for informed consent was waived.

463 consecutive patients with histopathologically confirmed gastric cancer were identified by reviewing the medical and pathological records between March 2010 and March 2011. The inclusion criteria were patients who (a) had not undergone previous gastrectomy or endoscopic surgery, (b) had undergone pre-operative water-distended stomach two-phase CT imaging, (c) had undergone surgical resection of gastric cancer within 6 weeks after pre-operative CT scanning and (d) had T4a gastric cancers and less advanced gastric cancers.

A total of 235 of the 463 patients were excluded for the following reasons: recurrent tumour after endoscopic submucosal dissection (ESD) or gastrectomy ($n=5$), insufficient gastric distension, which resulted in poor-quality images on which the gastric lesions were difficult to detect ($n=3$), unavailable thin-section CT data set (patients transferred from other hospitals, $n=4$), no surgery ($n=22$), ESD for early gastric cancer ($n=196$), an interval between the CT scan and resection longer than 6 weeks ($n=2$) and T4b gastric cancer because of difficulty in the interpretation of the perigastric fat and outer layer of the gastric wall ($n=3$). Finally, 228 patients [149 males, mean age $59.3 \text{ years} \pm 9.6$ (standard deviation) and 79 females, mean age $61.9 \text{ years} \pm 12.5$] were included in this study.

CT techniques

All MDCT imaging was performed according to the protocol used by our department. The CT images were obtained using several scanners: 16-MDCT scanner (Sensation 16®; Siemens Medical Systems, Erlangen, Germany) for 38 patients, 64-MDCT scanner (Somatom® Definition AS; Siemens Healthcare, Forchheim, Germany) for 156 patients and 128-MDCT scanner (Somatom Definition AS+; Siemens Healthcare) for 34 patients. An online real-time anatomy-adapted attenuation-based current modulation technique (Care Dose; Siemens Healthcare) was used in all patients.

All patients received 500 mL water as an oral contrast agent approximately 15 min before the examination and an additional 500 mL immediately prior to the study. In all patients, intravenous injection of an iodinated contrast material (Ultravist® 370; Bayer-Schering Pharma, Seoul, Republic of Korea) was administered at a dose of 1.5 mL kg^{-1} body weight with an injection rate of 3 mL s^{-1} using an automated pump through a 16–18 G intravenous catheter placed in the antecubital vein.

The parameters for multidetector row CT were as follows: detector collimation, 0.6–1.5 mm; table speed, 20–24 mm s^{-1} ; effective section thickness, 3.0 mm; reconstruction interval, 3.0 mm; gantry rotation time, 0.5 s; 200 reference mAs; 120 kVp and a 512×512 matrix.

Two sets of two-phase contrast-enhanced dynamic scans were obtained. The scan delay time was determined using the bolus-tracking technique (CARE Bolus; Siemens Medical Systems). To obtain time attenuation curves, a small region of interest was placed over the abdominal aorta. Portal venous phase CT scans were automatically initiated at 30 s after the contrast enhancement of the aorta reached the preferred point (100 HU), and delayed phase CT scans were acquired 90–110 s after the start of the contrast injection. The CT images were taken in either the supine or the prone position depending upon the site of the lesion during full inspiration, which was confirmed endoscopically. All contrast-enhanced CT images were directly interfaced to our picture archiving and communications system (PACS) (Maroview; Marotech, Seoul, Republic of Korea), which displayed all images on monitors (two monitors, 2048×2560 image matrices, 10-bit viewable grey scale and 145.9-ft-lambert luminescence).

Simple two-dimensional (2D) multiplanar-reconstructed reformatted images of the CT data allowed quick visualisation of the stomach in the sagittal and coronal planes.

Image analysis

Pre-operative contrast-enhanced CT examinations were retrospectively analysed on a PACS workstation independently by two abdominal radiologists (SK and TUK) with 11 years and 2 years, respectively, of clinical experience in abdominal CT, who were blinded to the histopathological stage of gastric cancer. However, the radiologists were aware of the diagnosis of gastric cancer, and the location of the tumours based on the pre-operative endoscopy findings. Transverse and MPR images were evaluated simultaneously. Differences in assessment were resolved by consensus.

First, a lesion was determined to be cancerous if there was gastric wall thickening or abnormal enhancement or combination of

Table 1. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of individual CT findings between patients with <T4a gastric cancer and T4a gastric cancer

CT findings	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Nodular or irregular outer contour	75.6	93.6	72.1	94.6	90.4
Haziness of the perigastric fat	75.6	83.4	50	94	82
Hyperattenuating serosa sign	63.4	96.8	81.3	92.3	90.8

the two compared with the adjacent normal gastric wall. Second, for all cancerous lesions, the following features were evaluated: nodular or an irregular outer layer of the gastric wall, haziness of the perigastric fat and the hyperattenuating serosa sign. Among these features, the former two are usually used to diagnose T4a gastric cancer on CT and the third was applied for CT evaluation of T4a gastric cancer. If a cancerous lesion was not detected, we considered these features to be negative. Haziness of the perigastric fat was defined as linear or reticular structures in the fatty layer surrounding the cancerous lesion. The hyperattenuating serosa sign was defined as a focal or diffuse thickened hyperattenuating outer layer of the gastric wall.

Pathological evaluation

The gross and histopathological features of gastric cancer were officially reported by a single pathologist (DYP) with 13 years of experience. T-stage was determined using the pathological findings of surgical specimens as reference standards according to the seventh edition of the AJCC and the UICC TNM classification.

Regarding histological types, gastric cancers are classified as either intestinal or diffuse. Intestinal or differentiated types include papillary and tubular adenocarcinomas, whereas diffuse or undifferentiated types included poorly differentiated adenocarcinomas and signet-ring cell carcinomas. A mucinous carcinoma can be interpreted as either intestinal or diffuse, depending upon the other predominant elements. Tumour size is reported in square centimetres and was calculated as follows: (long-axis diameter $\times$ 0.5) $\times$ (short-axis diameter $\times$ 0.5) $\times$ 3.14. The locations of tumours were recorded as fundus, body or antrum. When the tumour occupied more than two areas, the larger region affected by the tumour was selected.

Statistical analysis

For each of the three CT imaging findings, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for the diagnosis of T4a gastric cancer.

The significance of differences in the CT features between patients <T4a gastric cancer and T4a gastric cancer were evaluated with the Pearson χ^2 test.

Owing to the large number of patients with T1 gastric cancer, the significance of differences in the CT features between patients with T3 gastric cancer and T4a gastric cancer were evaluated with the Pearson χ^2 test or Fisher's exact test.

A multivariable stepwise logistic regression model was used to determine the best predictors of a differential diagnosis of <T4a gastric cancer and T4a gastric cancer and between T3 gastric

cancer and T4a gastric cancer, respectively. From these data, we determined the diagnostic performance of CT findings for differentiating T4a gastric cancer from other types.

A *p*-value of <0.05 was considered to indicate a statistically significant difference for all analyses. All statistical analyses were performed using the SPSS® software package (v. 11.0; SPSS, Chicago, IL).

RESULTS

Pathological findings

In the 228 patients with gastric cancer, the majority of the lesions [$n=138$ (61%)] were stage T1, confined to the mucosa or involving the submucosa. T stages of gastric cancer of 2, 3 and 4a were found in 25, 24 and 41 patients, respectively. Larger gastric tumours tended to correspond with deeper invasion. The size of tumours according to T stage was as follows: T1 (6.73 ± 10.9 cm²),

Figure 1. Diffuse-type gastric cancer with invasion of serosa (T4a) in a 64-year-old female. (a and b) Axial (a) and coronal multiplanar reconstruction (b) from intravenous contrast-enhanced CT show abnormal enhancement accompanied by wall thickening at lesser curvature of stomach body. All CT findings, including the nodular or irregular outer layer of gastric wall (black arrowhead), haziness of the perigastric fat (white arrowhead) and a hyperattenuating serosa sign (arrows), are seen. (c) Photomicrograph shows serosal invasion of gastric cancer (arrows). M, muscularis propria.

Table 2. Results of univariate and multivariate analyses of individual CT findings between patients with <T4a gastric cancer and T4a gastric cancer

CT findings	<T4a (n=187) ^a	T4a (n=41) ^a	p-value ^b	Multivariate odds ratio ^c
Nodular or irregular outer contour	12	31	0.000	6.128
Haziness of the perigastric fat	31	31	0.000	—
Hyperattenuating serosa sign	6	26	0.000	5.646

^aData are numbers of neoplasms.

^bA p-value of <0.05 indicates a significantly different CT finding between two groups (<T4a and T4a gastric cancer) in univariate analysis.

^cThe final statistical model included only those predictor variables that were found at multivariate analysis to be statistically significant.

T2 ($8.65 \pm 10.56 \text{ cm}^2$), T3 ($27.63 \pm 25.59 \text{ cm}^2$) and T4a ($45.77 \pm 45.88 \text{ cm}^2$). The histological types of gastric cancer included 112 intestinal-type and 116 diffuse-type lesions. The locations of gastric cancer included the fundus (n=8), body (n=125) and antrum (n=95).

CT features differentiating <T4a gastric cancer from T4a gastric cancer

Table 1 summarises the CT features in patients with <T4a gastric cancer and T4a gastric cancer. All CT findings were seen more often in T4a gastric cancer than in <T4a gastric cancer (Figure 1). In univariate analysis, all CT findings, including nodular or an irregular outer layer of gastric wall, haziness of the perigastric fat and the hyperattenuating serosa sign, demonstrated a statistically significant association with the reference standard ($p < 0.05$). The CT imaging features with the highest sensitivity were nodular or an irregular outer layer of the gastric wall and haziness of the perigastric fat (75.6%), and the CT imaging feature with the highest specificity was the hyperattenuating serosa sign (96.8%). The results of multivariate logistic analysis indicated that the most significant findings that differentiate between <T4a and T4a gastric cancers are nodular or an irregular outer layer of the gastric wall and the hyperattenuating serosa sign (Table 2).

CT features differentiating T3 gastric cancer from T4a gastric cancer

Table 3 summarises the CT features observed in patients with T3 gastric cancer and T4a gastric cancer. Also, all CT findings were seen more often in T4a gastric cancer than T3 gastric cancer. In univariate analysis, nodular or an irregular outer layer of the gastric wall and the hyperattenuating serosa sign were significant in differentiating between T3 and T4a. Multivariate logistic analysis showed that the hyperattenuating serosa sign was an independent predictive factor in differentiating between T3 and T4a gastric cancers with six false-positive findings (Figure 2, Table 4). The hyperattenuating serosa sign had an estimated odds ratio of 4.210 (95% confidence interval: 1.581–11.214; $p = 0.004$). The sensitivity, specificity, PPV, NPV and accuracy

of the sign for CT differentiation between T3 and T4a gastric cancers were 63.4%, 75.0%, 81.3%, 54.5% and 67.7%, respectively.

DISCUSSION

Our results showed that all findings including nodular or an irregular outer layer of the gastric wall, haziness of the perigastric fat and the hyperattenuating serosa sign were significant in differentiation of <T4a gastric cancer and T4a gastric cancer. Multivariate logistic analysis showed that the presence of nodular or an irregular outer gastric wall and the hyperattenuating serosa sign were independently associated with T4a gastric cancer compared with <T4a gastric cancer. On application of previous CT criteria, *i.e.* nodular or an irregular outer layer and haziness of the perigastric fat, the accuracies for T staging of T4a were 90.4% and 82%, respectively. Our results are similar to those of published studies of T4a gastric cancer patients [9–12]. However, the accuracy may be overestimated because a large number of patients with T1 gastric cancer were included in the comparison group. T1a gastric cancer tends to be undetectable on 2D CT images and T1b gastric cancer frequently shows only mucosal thickening with enhancement [15]. Therefore, gastric cancers overstaged as T4a gastric cancer on CT are more likely to be pathological T2 or T3 but not T1. In this study, the majority of the T1 gastric cancers were undetected on CT and only 9 (6.5%) cases of detected T1 gastric cancers showed haziness of the perigastric fat.

When we compared T4a with T3 gastric cancer, we found that T4a gastric cancer was associated with an increased incidence of nodular or an irregular outer layer of the gastric wall and the hyperattenuating serosa sign. We found that the hyperattenuating serosa sign was the only independent significant predictor of T4a gastric cancer compared with T3 gastric cancer in a multivariate analysis.

Current multidetector CT with thin collimation provides isotropic imaging of the stomach, which allows high-quality

Table 3. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of individual CT findings between patients with T3 gastric cancer and T4a gastric cancer

CT findings	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Nodular or irregular outer contour	75.6	50	72.1	54.5	66.2
Haziness of the perigastric fat	75.6	29.2	64.6	41.2	58.5
Hyperattenuating serosa sign	63.4	75	81.3	54.5	67.7

Figure 2. Intestinal-type gastric cancer with invasion of serosa (T4a) in a 74-year-old male. (a and b) Axial (A) and coronal multiplanar reconstruction (B) from intravenous contrast-enhanced CT show abnormal enhancement on lesser curvature of stomach upper body. A hyperattenuating serosal sign (arrows) is seen, but perigastric fat surrounding the gastric lesion appears to be clear and surface of the gastric lesion appears to be smooth. (c) Photomicrograph of corresponding pathological specimen shows serosa infiltration by cancer cells (arrow). M, muscularis propria, T, tumour.

multiplanar reformation. As a result, high-quality MPR images have dramatically improved the visualisation of fine anatomical details of the gastric wall. Despite these advancements in MDCT technology, its ability to differentiate between the

layers of the gastric wall is limited. As a result, overstaging and understaging are common problems encountered in T staging of gastric cancer on CT. Also, the same problem was encountered in CT staging of T4a gastric cancer, although investigators in prior studies have suggested a relatively high accuracy in T4a gastric cancer using the established criteria. In a recent study [12], 22.6% of T2 or T3 stage lesions were overstaged as T4a. According to previous studies [10,16–18], putative causes of overstaging as T4a are as follows: (1) differentiating perigastric infiltration from gastric cancer and perigastric inflammation or fibrosis on CT images can be difficult; (2) tortuous engorged vascular or lymphatic structures often make irregular strands along the gastric border mimicking the true irregular outer gastric border; (3) the tumour can sometimes deform the outer surface of the gastric wall owing to compression of the serosa; (4) in cases of severe cachexia, evaluation of the perigastric fat plane and outer surface of the gastric wall can also be limited owing to depletion of perigastric fat.

Our study showed that the haziness of perigastric fat was not significantly different between T3 and T4a gastric cancer, probably owing to these causes (Figure 3). In our results, the mean size of T3 gastric tumours with a lobulated outer margin was larger than T3 tumours without the lobulated outer margin (37.66 cm^3 vs 17.6 cm^3). We supposed this result was attributable to compression of the serosa by the larger tumour, leading to a false positive.

We hypothesised that the hyperattenuating serosa sign may be associated with the CT feature of scirrhous metastases in the gastrointestinal tract. Ha et al [19] reported that when the tumour infiltrates all layers, it expands the mucosa, submucosa and serosa rather than the muscularis propria owing to the more tightly packed muscle cells of the latter tissue. Therefore, the muscularis propria is the least thickened hyperattenuating layer in scirrhous metastasis; Gollub et al [14] termed this feature the malignant target sign. Histologically, the gastric muscularis propria, as in other parts of the digestive tract, is thicker and stronger than the mucosa, submucosa or subserosa layers, thus acting as a firm barrier [20]. Therefore, we speculated that the hyperattenuating serosa sign could be applied to evaluation of serosal invasion of gastric cancer. We assumed that the less hyperattenuating layer seen in the hyperattenuating serosa sign represented the muscularis propria less infiltrated by the tumour. Multivariate analysis supported our hypothesis that the hyperattenuating serosa sign could be useful for evaluating serosal invasion of gastric cancer. Our assumption is in agreement with that of Shimizu et al [10] who reported that the low-attenuating

Table 4. Results of univariate and multivariate analyses of individual CT findings between patients with T3 gastric cancer and T4a gastric cancer

CT findings	T3 ($n=24$) ^a	T4a ($n=41$) ^a	p -value ^b	Multivariate odds ratio ^c
Nodular or irregular outer contour	12	31	0.035	—
Haziness of the perigastric fat	17	31	0.672	—
Hyperattenuating serosa sign	6	26	0.004	4.210

^aData are numbers of neoplasms.

^bA p -value of <0.05 indicates a significant different CT finding between two groups (T3 and T4a gastric cancer) in univariate analysis.

^cThe final statistical model included only those predictor variables that were found at multivariate analysis to be statistically significant.

Figure 3. Intestinal type gastric cancer with invasion of subserosa (T3) in a 75-year-old woman. A, Axial from intravenous contrast-enhanced CT show ulcerative tumour at lesser curvature of stomach upper body. Perigastric fat infiltrating (arrow) is seen around ulcerative mass. B. Photomicrograph of corresponding pathologic specimen shows subserosa invasion by cancer cells (arrows). M, muscularis propria; SS, subserosa; T, tumour.

abnormal second layer corresponded to diffuse scattering of cancer cells, mainly in the proper muscle layer with desmoplastic change and inflammatory reaction, and that a high-attenuating abnormal third layer of the gastric wall suggested serosal infiltration by the tumour.

Although multivariate analysis revealed the significant CT features in differentiating T4a from T3 gastric cancer, the hyperattenuating serosa sign is not sensitive for T4a gastric cancer (63.4%). Of the 15 tumours that did not show the hyperattenuating serosa sign, the majority ($n=13$) were diffuse carcinoma. We believe that this understaging was partly related to the hypovascularity of

diffuse carcinoma compared with that of the intestinal carcinoma [21].

We found that the hyperattenuating serosa sign had a relatively high PPV for T4a gastric cancer (81.3%) and a moderate specificity (75%), suggesting that this finding can predict serosal invasion. On diagnosis of T4a or more invasive gastric cancer using MDCT, patients are increasingly undergoing staging laparoscopy to recognise peritoneal disease because free cancer cells seeded from tumours invading the serosa commonly disseminate throughout the peritoneum [22]. Several recent retrospective studies have reported the effects of neoadjuvant chemotherapy in gastric cancer patients with positive peritoneal cytology [23,24]. Therefore, particular attention should be paid to evaluating peritoneal dissemination when the hyperattenuating serosa sign is found on MDCT. Also, awareness of pre-operative serosal invasion can obviate the need for laparoscopic gastrectomy, which can promote exfoliation of free cancer cells from the gastric serosa [25–27].

This study has several limitations. First, a large number of T1 stage neoplasias were included. This could be attributed to the aggressive screening programs owing to the high incidence of gastric cancer. Therefore, we also compared T3 and T4a gastric cancers. Second, because we did not perform a one-to-one correlation of CT images and histological features, which make it uncertain whether the less hyperattenuating layer seen in the hyperattenuating serosa sign actually represents the muscularis propria less infiltrated by the tumour. Third, the retrospective design of our study induced selection bias by limiting our study to patients with gastric cancer who underwent CT and surgery.

Finally, our patients underwent CT using various CT protocols and scanners, from a 16-MDCT to a 128-MDCT scanner. However, we attempted to keep the scanning parameters as consistent as possible.

We concluded that radiologists can use the hyperattenuating serosa sign to help differentiate gastric cancer invading the serosa, which will facilitate planning of the optimal pre-operative evaluation and treatment, such as pre-operative peritoneal lavage, for patients with tumours invading the gastric serosa.

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REFERENCES

1. Kamangar F, Dores GM, Anderson WF. Patterns of cancer incidence, mortality, and prevalence across five continents: defining priorities to reduce cancer disparities in different geographic regions of the world. *J Clin Oncol* 2006;24: 2137–50. doi: 10.1200/JCO.2005.05.2308
2. Siewert JR, Böttcher K, Stein HJ, Roder JD. Relevant prognostic factors in gastric cancer: ten-year results of the German Gastric Cancer Study. *Ann Surg* 1998;228: 449–61.
3. Kunisaki C, Akiyama H, Nomura M, Matsuda G, Otsuka Y, Ono HA, et al. Surgical outcomes in patients with T4a

- gastric carcinoma. *J Am Coll Surg* 2006; 202:223–30. doi: [10.1016/j.jamcollsurg.2005.10.020](https://doi.org/10.1016/j.jamcollsurg.2005.10.020)
4. Jatzko GR, Lisborg PH, Denk H, Klimpfinger M, Stettner HM. A 10-year experience with Japanese-type radical lymph node dissection for gastric cancer outside of Japan. *Cancer* 1995;76:1302–12.
 5. Roviello F, Marrelli D, de Manzoni G, Morgagni P, Di Leo A, Saragoni L, et al. Prospective study of peritoneal recurrence after curative surgery for gastric cancer. *Br J Surg* 2003;90:1113–9. doi: [10.1002/bjs.4164](https://doi.org/10.1002/bjs.4164)
 6. Ott K, Lordick F, Herrmann K, Krause BJ, Schuhmacher C, Siewert JR. The new credo: induction chemotherapy in locally advanced gastric cancer: consequences for surgical strategies. *Gastric Cancer* 2008;11:1–9. doi: [10.1007/s10120-007-0448-1](https://doi.org/10.1007/s10120-007-0448-1)
 7. Yoshikawa T, Sasako M, Yamamoto S, Sano T, Imamura H, Fujitani K, et al. Phase II study of neoadjuvant chemotherapy and extended surgery for locally advanced gastric cancer. *Br J Surg* 2009;96:1015–22. doi: [10.1002/bjs.6665](https://doi.org/10.1002/bjs.6665)
 8. Chen CY, Hsu JS, Wu DC, Kang WY, Hsieh JS, Jaw TS, et al. Gastric cancer: preoperative local staging with 3D multi-detector row CT—correlation with surgical and histopathologic results. *Radiology* 2007;242: 472–82. doi: [10.1148/radiol.2422051557](https://doi.org/10.1148/radiol.2422051557)
 9. Kim HJ, Kim AY, Oh ST, Kim JS, Kim KW, Kim PN, et al. Gastric cancer staging at multi-detector row CT gastrography: comparison of transverse and volumetric CT scanning. *Radiology* 2005;236:879–85. doi: [10.1148/radiol.2363041101](https://doi.org/10.1148/radiol.2363041101)
 10. Shimizu K, Ito K, Matsunaga N, Shimizu A, Kawakami Y. Diagnosis of gastric cancer with MDCT using the water-filling method and multiplanar reconstruction: CT-histologic correlation. *Am J Roentgenol* 2005;185: 1152–8. doi: [10.2214/AJR.04.0651](https://doi.org/10.2214/AJR.04.0651)
 11. Kumano S, Murakami T, Kim T, Hori M, Iannaccone R, Nakata S, et al. T staging of gastric cancer: role of multi-detector row CT. *Radiology* 2005;237:961–6. doi: [10.1148/radiol.2373041380](https://doi.org/10.1148/radiol.2373041380)
 12. Furukawa K, Miyahara R, Itoh A, Ohmiya N, Hirooka Y, Mori K, et al. Diagnosis of the invasion depth of gastric cancer using MDCT with virtual gastroscopy: comparison with staging with endoscopic ultrasound. *Am J Roentgenol* 2011;197:867–75. doi: [10.2214/AJR.10.5872](https://doi.org/10.2214/AJR.10.5872)
 13. Kim AY, Kim HJ, Ha HK. Gastric cancer by multidetector row CT: preoperative staging. *Abdom Imaging* 2005;30:465–72. doi: [10.1007/s00261-004-0273-5](https://doi.org/10.1007/s00261-004-0273-5)
 14. Gollub MJ, Schwartz MB, Shia J. Scirrhous metastases to the gastrointestinal tract at CT: the malignant target sign. *Am J Roentgenol* 2009;192:936–40. doi: [10.2214/AJR.08.1152](https://doi.org/10.2214/AJR.08.1152)
 15. Lee IJ, Lee JM, Kim SH, Shin CI, Lee JY, Kim SH, et al. Diagnostic performance of 64-channel multidetector CT in the evaluation of gastric cancer: differentiation of mucosal cancer (T1a) from submucosal involvement (T1b and T2). *Radiology* 2010; 255:805–14. doi: [10.1148/radiol.10091313](https://doi.org/10.1148/radiol.10091313)
 16. Lee MH, Choi D, Park MJ, Lee MW. Gastric cancer: imaging and staging with MDCT based on the 7th AJCC guidelines. *Abdom Imaging* 2012;37:531–40. doi: [10.1007/s00261-011-9780-3](https://doi.org/10.1007/s00261-011-9780-3)
 17. Kim YN, Choi D, Kim SH, Kim MJ, Lee SJ, Lee WJ, et al. Gastric cancer staging at isotropic MDCT including coronal and sagittal MPR images: endoscopically diagnosed early vs. advanced gastric cancer. *Abdom Imaging*. 2009;34:26–34. doi: [10.1007/s00261-008-9380-z](https://doi.org/10.1007/s00261-008-9380-z)
 18. Chen CY, Wu DC, Kang WY, Hsu JS. Staging of gastric cancer with 16-channel MDCT. *Abdom Imaging* 2006;31:514–20. doi: [10.1007/s00261-005-0218-7](https://doi.org/10.1007/s00261-005-0218-7)
 19. Ha HK, Jee KR, Yu E, Yu CS, Rha SE, Lee IJ, et al. CT features of metastatic linitis plastica to the rectum in patients with peritoneal carcinomatosis. *Am J Roentgenol* 2000;174:463–6. doi: [10.2214/ajr.174.2.1740463](https://doi.org/10.2214/ajr.174.2.1740463)
 20. Son HJ, Myung W, Yoo HS, Park SH, Song SY, Kwon YD, et al. Prognostic indicators of gastric carcinoma confined to the muscularis propria. *Histopathology* 2007;51:105–10. doi: [10.1111/j.1365-2559.2007.02725.x](https://doi.org/10.1111/j.1365-2559.2007.02725.x)
 21. Adachi Y, Mori M, Enjoji M, Sugimachi K. Microvascular architecture of early gastric carcinoma. Microvascular-histopathologic correlates. *Cancer* 1993;72:32–6.
 22. Fujiwara Y, Takiguchi S, Nakajima K, Miyata H, Yamasaki M, Kurokawa Y, et al. Neoadjuvant intraperitoneal and systemic chemotherapy for gastric cancer patients with peritoneal dissemination. *Ann Surg Oncol* 2011;18:3726–31. doi: [10.1245/s10434-011-1770-8](https://doi.org/10.1245/s10434-011-1770-8)
 23. Badgwell B, Cormier JN, Krishnan S, Yao J, Staerkel GA, Lupo PJ, et al. Does neoadjuvant treatment for gastric cancer patients with positive peritoneal cytology at staging laparoscopy improve survival? *Ann Surg Oncol* 2008;15:2684–91. doi: [10.1245/s10434-008-0055-3](https://doi.org/10.1245/s10434-008-0055-3)
 24. Lorenzen S, Panzram B, Rosenberg R, Nekarda H, Becker K, Schenk U, et al. Prognostic significance of free peritoneal tumor cells in the peritoneal cavity before and after neoadjuvant chemotherapy in patients with gastric carcinoma undergoing potentially curative resection. *Ann Surg Oncol* 2010;17:2733–9.
 25. Adachi Y, Kitano S, Sugimachi K. Surgery for gastric cancer: 10-year experience worldwide. *Gastric Cancer* 2001;4:166–74. doi: [10.1007/s101200100018](https://doi.org/10.1007/s101200100018)
 26. Uyama I, Sugioka A, Sakurai Y, Komori Y, Hanai T, Matsui H, et al. Hand-assisted laparoscopic function-preserving and radical gastrectomies for advanced-stage proximal gastric cancer. *J Am Coll Surg* 2004;199: 508–15. doi: [10.1016/j.jamcollsurg.2004.04.020](https://doi.org/10.1016/j.jamcollsurg.2004.04.020)
 27. Kim MC, Kim KH, Kim HH, Jung GJ. Comparison of laparoscopy-assisted by conventional open distal gastrectomy and extraperigastric lymph node dissection in early gastric cancer. *J Surg Oncol* 2005;91: 90–4. doi: [10.1002/jso.20271](https://doi.org/10.1002/jso.20271)