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GASTROINTESTINAL

Differentiation of early gastric cancer with ulceration and resectable advanced gastric cancer using multiphasic dynamic multidetector CT

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Abstract

Objectives Early gastric cancer with ulceration (EGC-U) mimics advanced gastric cancer (AGC), as EGC-Us and ACGs often have similar endoscopic appearance to ulceration. The purpose of this retrospective study was to determine whether multiphasic dynamic multidetector CT (MDCT) can help differentiate EGC-Us from AGCs.

Methods Patients with EGC-Us with ulcer stages Ul-III or IV and AGCs with tumour stages T2 to T4a were enrolled. MDCT images were obtained 40 s (arterial phase), 70 s (portal phase) and 240 s (delayed phase) after injection of non-ionic contrast material. Two readers independently measured the attenuation values of the lesions by placing regions of interest. We compared the EGC-Us and AGCs using the mean attenuation values in each phase and peak enhancement phase. We analysed the diagnostic performance of CT for differentiating EGC-Us from AGCs.

Results Forty cases (16 EGC-Us and 24 AGCs) were analysed. The mean attenuation values of the EGC-Us were significantly lower than those of the AGCs in both the arterial and portal phases (all $p<0.0001$ for each reader). The peak enhancement was significantly different between the EGC-Us and AGCs for both readers (Reader 1, $p=0.0131$; Reader 2, $p=0.0006$).

Conclusion Multiphasic dynamic contrast-enhanced MDCT can help differentiate EGC-Us from AGCs.

Key Points

- *Early gastric cancer with ulceration and advanced gastric cancer have similar endoscopic appearances.*
- *EGC-U shows significantly lower attenuation values in both arterial and portal phases.*
- *Multiphasic dynamic contrast-enhanced MDCT differentiates EGC-U from AGC.*

Keywords Gastric cancer · Gastric ulcer · Computed tomography · Three-dimensional image · Gastroscopy

Abbreviations

3D	Three-dimensional
AGC	Advanced gastric cancer
EGC-U	Early gastric cancer with ulceration
EUS	Endoscopic ultrasound
FOV	Field of view
MDCT	Multidetector computed tomography
NPV	Negative predictive value
PPV	Positive predictive value
ROC	Receiver operator characteristics
ROI	Region of interest

Introduction

It is sometimes difficult to differentiate malignant from benign gastric ulcers on the basis of macroscopic endoscopic findings [1, 2]. Most early gastric cancers involve a depressed or

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ulcerated component believed to go through a 'malignant cycle' consisting of ulceration followed by healing and re-ulceration, which then grow as early gastric cancer with ulceration (EGC-U) [3]. According to a previous report, EGC-U mimics advanced gastric cancer (AGC), as EGC-U and AGC have similar endoscopic appearances with ulceration [4].

It is crucial to differentiate EGC-U from AGC, because the depth of tumour invasion of gastric cancer is associated with the survival rate: the deeper the tumour invasion, the lower the survival rate [5]. In addition, the treatment options for EGC-U and AGC differ. Deeper lymph node dissection or neoadjuvant chemotherapy may be needed for the curative treatment of patients with AGC. Endoscopic ultrasound (EUS) is regarded as the best diagnostic method for the tumour-stage diagnosis of gastric cancer; however, accuracy rates of only 63–70 % were reported for the tumour-stage diagnosis of EGC-U by EUS [6, 7].

Computed tomography (CT) is a standard preoperative examination for the staging of gastric cancer, used mainly to determine the presence/absence of nodal or distant metastases. In recent years, multidetector CT (MDCT) with air distension of the stomach has improved the imaging resolution and facilitated three-dimensional (3D) image reconstruction [8, 9]. With the use of a contrast agent, MDCT has performed well at diagnosing the depth of cancer invasion, comparable to EUS [10, 11]. In addition, the periulcer enhancement pattern on MDCT was shown to be a good indicator for differentiating malignant from benign gastric ulcers [1].

The purpose of our present study was to (a) determine whether multiphasic dynamic MDCT can help differentiate EGC-Us from AGCs and (b) to evaluate the diagnostic performance in differentiating these tumours.

Materials and methods

Patient population

This retrospective study was approved by our institutional review board, and the requirements for informed consent were waived. From January 2006 to December 2012, 186 consecutive patients with gastric cancer were preoperatively evaluated by gastroscopy and contrast-enhanced MDCT at our institution. All the patients were pathologically confirmed to have gastric adenocarcinoma after gastrectomy. Tumour stages were stated on the patients' operation records according to the Japanese Classification of Gastric Carcinoma (third English edition) [12]. Concomitant ulcerative change was also stated on the postoperative pathological records. The depth of the ulcers was classified into three grades: Ul-II, which involves the submucosal layer of the stomach; Ul-III, which involves the proper muscle layer; and Ul-IV, which penetrates the proper muscle layer and involves the serosa [13].

Thirty-eight patients with EGC-Us with the ulcer stage of Ul-III or IV and 68 patients with AGCs with the tumour stage of T2 to T4a were enrolled in the present study for our examination of the correlation with the affected layer of gastric wall. We excluded gastric cancers of the oesophagogastric junction (n=21), protruding-type gastric cancers (Borrmann type 1) (n=6), and diffuse infiltrative type gastric cancers (Borrmann type 4) (n=11) because they defeated the purpose of this study: cancers of the oesophagogastric junction cannot be accurately analysed without optimal luminal distension with the use of transcatheter air inflation [14]. Borrmann type 1 and 4 cancers were easily distinguishable from EGC-U on endoscopy. Patients who underwent neoadjuvant chemotherapy (n=10) or previous gastrectomy (n=4) were also excluded. Finally, 54 patients were included as the subjects of this study.

CT protocol

All patients underwent imaging with a 64-MDCT system (Aquilion 64, Toshiba Medical Systems, Tokyo, Japan). After an overnight fast, each patient ingested 5.25 g of an effervescent agent (Baros Effervescent Granules-S, Horii Pharmaceutical Industries, Saitama, Japan) with a small amount of water just before the scanning to achieve gastric pouch distention. The patient was then given an intramuscular injection of 20 mg of scopolamine (Buscopan, Boehringer Ingelheim, Ingelheim am Rhein, Germany) to suppress peristalsis. The scanning covered the entire stomach during a single breath-hold.

The imaging parameters were as follows: rotation time, 0.5 s; section thickness and intervals, 1 mm; beam collimation, 1 mm; pitch, 53; 120 kVp; 200 mAs; field of view (FOV), 32 cm^2; matrix, 512×512; voxel size, 0.625×0.625×1 mm^3. CT images were obtained 40 s (arterial phase), 70 s (portal phase) and 240 s (delayed phase) after an infusion of 2 ml/kg of non-ionic contrast material (Iopamiron370; Bayer Health Care, Osaka, Japan) at a rate of 3 ml/s. The patient's position was supine in the arterial and portal phases for the clinical interpretation to obtain angiographic images and to investigate the liver metastasis. In the delayed phase, the regular patient position was supine, and in some cases the position was prone if the lesion was hidden by intraluminal fluid in the arterial or portal phases in the supine position. All MDCT datasets were transferred to a commercially available workstation equipped with image reconstruction software (Synapse Vincent, Fujifilm, Tokyo).

CT image analyses

Analysis of the patients' CT images was performed by two gastrointestinal abdominal radiologists with 7 and 12 years of experience. Both readers were blinded to all clinical and

pathological data except for the endoscopic findings. They independently reviewed and analysed the CT images on the workstation. They identified a gastric lesion on virtual endoscopy using optical endoscopic findings as a reference. The lesion was determined to be cancerous when the gastric wall showed focal thickening of ≥6 mm [15]. Cases which were not visible on virtual endoscopy due to a collapsed gastric lumen or intraluminal fluid were excluded.

After localization of the gastric lesion, the radiologists determined the largest tumour section on transverse or coronal or sagittal images using multiplanar reconstruction. They measured the attenuation value by placing circular regions of interest (ROIs), as large as possible, in three different parts of the tumour tissue excluding any areas of necrosis or vessel structures within the lesion. The mean attenuation values of the circular ROI were used, and the mean values of the three different areas were calculated.

Endoscopic image analyses

Endoscopic examination is performed first for diagnosing gastric cancers, and the endoscopic diagnosis is usually thought to be a reference standard. An analysis of the endoscopic images was also performed in this study to compare the endoscopic diagnoses with the CT diagnoses. The endoscopic image analyses was performed after the CT image analyses. Two endoscopists with 6 and 9 years of endoscopic experience blinded to the objective of this study interpreted the endoscopic images of all cases except those that were excluded from the CT image analyses described above because of non-visualization on CT. The two endoscopists interpreted the endoscopic images independently and had to diagnose the lesion as EGC or AGC according to the Japanese Classification of Gastric Carcinoma [11].

Statistical analysis

We compared the mean attenuation values of the EGC-Us and AGCs in each phase using Student's t-test for two readers. Interobserver variability for the attenuation measurements of the two readers was analysed by calculating the intraclass correlation coefficient (ICC) (0.00–0.20 poor, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 good, and 0.81–1.00 excellent correlation). We performed a receiver operating characteristic (ROC) analysis to determine the optimal cut-off value of the attenuation value for differentiating EGC-Us from AGCs for each reader. We determined the 'peak enhancement phase' in which the lesion showed the highest attenuation value among the three phases for each case, and we compared the peak enhancement of the EGC-Us and AGCs using Chi-square tests. We calculated the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of the CT for differentiating EGC-Us from AGCs based on the above-described parameters.

We also analysed both the diagnostic performance of endoscopy in differentiating EGC-Us from AGCs and the interobserver agreement between the two endoscopists, using κ statistics. A κ value of 0.00–0.20 indicated poor agreement, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 good and 0.81–1.00 excellent. Differences with p-values less than 0.05 were accepted as significant. The statistical analyses were

Table 1 Characteristics of 40 patients included for CT and endoscopic analysis

	ECG-U (n=16)	AGC (n=24)	*p*-value
Sex			0.55
Male	5	11	
Female	11	13	
Mean age (y, range)	67 (55–79)	63 (35–84)	0.049
Tumour stage			
T1	16		
T2		8	
T3		10	
T4a		6	
Histology			0.94
Differentiated	5	6	
Undifferentiated	11	18	
Ulcer stage			
III	13		
IV	3		
Location			0.28
U	2	4	
M	12	13	
L	2	7	
Mean lesion size (mm, range)	35 (12–56)	45 (10–65)	0.033

EGC-U early gastric cancer with ulceration, *AGC* advanced gastric cancer, *U* upper, *M* middle, *L* lower

Table 2 Mean CT attenuation value of EGC-U and AGC in each phase

	EGC-U (n=16)	AGC (n=24)	*p*-value
Arterial			
Reader 1	68.6 (56.0–81.3)	113.0 (102.6–123.3)	<0.0001
Reader 2	64.2 (51.1–77.3)	107.4 (96.7–118.1)	<0.0001
Portal			
Reader 1	76.5 (65.4–87.7)	117.1 (108.0–126.2)	<0.0001
Reader 2	78.3 (65.0–91.6)	122.5 (111.6–133.4)	<0.0001
Delayed			
Reader 1	93.5 (83.6–103.4)	101.1 (93.0–109.1)	0.24
Reader 2	93.4 (83.8–102.9)	99.5 (91.7–107.4)	0.32

Data are mean attenuation values in Hounsfield units, with 95 % confidence intervals in parentheses

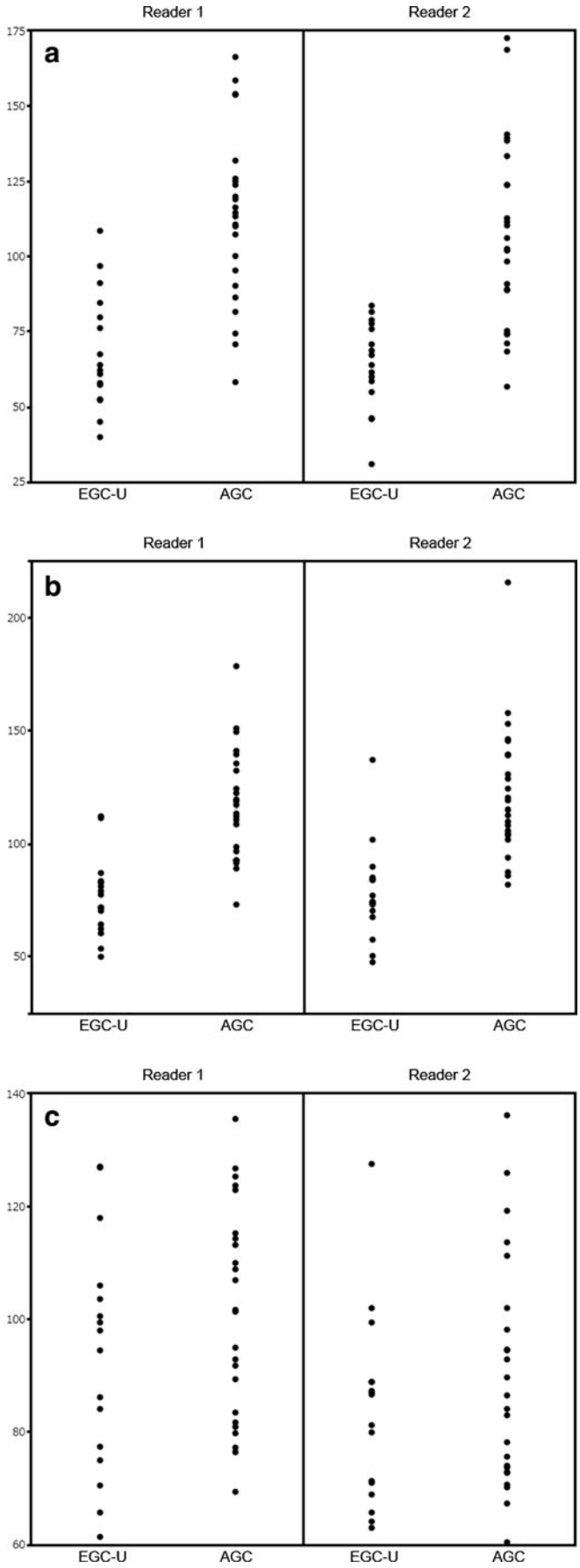

Fig. 1 Attenuation values of early gastric cancer with ulceration (EGC-U) and advanced gastric cancer (AGC) measured by two readers. Scatterplots illustrate the attenuation values of the (**a**) arterial, (**b**) portal and (**c**) delayed phases of EGC-U and AGC according to both readers. The mean attenuation values of the EGC-Us were significantly lower than those of the AGCs in both the arterial and portal phases (both $p<0.0001$) according to both readers. There was no significant between-group difference in the delayed phase

Table 3 Peak enhancement phase of EGC-U and AGC

	EGC-U (n=16)	AGC (n=24)	*p*-value
Reader 1			
Arterial	2	6	0.0131
Portal	2	11	
Delayed	12	7	
Reader 2			
Arterial	2	6	0.0006
Portal	2	14	
Delayed	12	4	

performed using SPSS 18 for Windows software (SPSS, Chicago, IL, USA).

Results

Of the 54 cases, 40 (16 EGC-Us and 24 AGCs) were available for attenuation value measurement. Eight of the EGC-Us and six of the AGCs were not detectable on virtual endoscopy by CT due to a collapsed gastric lumen or intraluminal fluid. The patients' characteristics are presented in Table 1. The mean age of the patients was 67 years for EGC-U and 63 years for AGC. The mean lesion size was 35 mm for the EGC-Us and significantly larger for the AGCs at 45 mm (p=0.033). The histology type (differentiated vs. undifferentiated) was not significantly different between the two groups.

In the CT image analyses, the mean attenuation values of the EGC-U cases were significantly lower than those of the AGC cases in both the arterial and portal phases (both p<0.0001) according to both readers. There was no significant between-group difference in the delayed phase. The results of the CT image analyses are shown in Table 2 and Fig. 1. The interobserver reproducibility for measuring the attenuation values between the two readers was good (both ICCs, 0.77) for the arterial and delayed phase, and excellent (ICC 0.89) for the portal phase. The Chi-square test results showed that the peak enhancement was significantly different between the EGC-Us and AGCs for both readers (reader 1, p=0.0131; reader 2, p=0.0006); most of the EGC-U cases had peak enhancement in the delayed phase (Table 3).

The results of diagnostic performance of CT for differentiating EGC-Us from AGCs based on the mean attenuation values and the peak enhancement phase are shown in Table 4. When the optimal cut-off was set at 84.7 Hounsfield unit (HU) and 83.7 HU in the arterial phase, the values obtained by Reader 1 and Reader 2, respectively, were as follows: sensitivity 81.3 % and 100.0 %, specificity 83.3 % and 75.0 %, PPV 76.5 % and 72.7 %, NPV 87.0 % and 100.0 %, and accuracy 82.7 % and 85.0 %.

When the cut-off value in the portal phase was set at 87.4 HU and 85.3 HU, the values obtained by Reader 1 and Reader 2, respectively, were as follows: sensitivity 87.5 % and 81.3 %, specificity 95.8 % and 95.8 %, PPV 93.3 % and 92.9 %, NPV 92.0 % and 88.5 %, and accuracy 92.5 % and 90.0 %. When the peak enhancement in the delayed phase was a positive finding for EGC-U, the values obtained by Reader 1 and Reader 2, respectively, were as follows: sensitivity 75.0 % and 75.0 %, specificity 70.8 % and 83.3 %, PPV 63.2 % and 75.0 %, NPV 81.0 % and 83.3 % and accuracy 72.5 % and 80.0 %.

In the endoscopic image analyses, the values obtained by Endoscopist 1 and Endoscopist 2, respectively, were as follows: sensitivity 93.8 % and 81.3 %, specificity 54.2 % and 66.7 %, PPV 57.7 % and 61.9 %, NPV 92.9 % and 84.2 % and

Table 4 Diagnostic performance of CT and endoscopy

	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	AUC
CT						
Attenuation value						
Arterial						
Reader 1	81.3 (13/16)	83.3 (20/24)	76.5 (13/16)	87.0 (20/24)	82.5 (33/40)	0.91
Reader 2	100.0 (16/16)	75.0 (18/24)	72.7 (16/14)	100.0 (18/18)	85.0 (34/40)	0.90
Portal						
Reader 1	87.5 (14/16)	95.8 (23/24)	93.3 (14/15)	92.0 (23/25)	92.5 (37/40)	0.93
Reader 2	81.3 (13/16)	95.8 (23/26)	92.9 (13/14)	88.5 (23/26)	90.0 (36/40)	0.93
Peak enhancement						
Reader 1	75.0 (12/16)	70.8 (17/24)	63.2 (12/19)	81.0 (17/21)	72.5 (29/40)	
Reader 2	75.0 (12/16)	83.3 (20/24)	75.0 (12/16)	83.3 (20/24)	80.0 (32/40)	
Endoscopy						
Endoscopist 1	93.8 (15/16)	54.2 (13/24)	57.7 (15/26)	92.9 (13/14)	70.0 (28/40)	
Endoscopist 2	81.3 (13/16)	66.7 (16/24)	61.9 (13/21)	84.2 (16/19)	72.5 (29/40)	

Numbers in parentheses are numerators and denominators and indicate the absolute numbers for calculation of the parameters

accuracy 70.0 % and 72.5 %. The agreement was good for the endoscopic diagnosis (κ, 0.72). The diagnostic performance of endoscopy is also shown in Table 4. Examples of the CT and endoscopic images of EGC-U and AGC are given in Figs. 2 and 3.

Discussion

Our study results showed that the EGC-Us had significantly lower attenuation values compared to the AGCs in both the arterial and portal phases according to the attenuation measurement by each reader. Several studies have revealed that gastric cancers show neovascularity during the arterial to capillary phase in vivo [16, 17], and that the use of contrast-enhanced CT allowed the retrospective detection of moderate to marked enhancement in the early phase in most gastric cancers [18–20]. However, gastric cancers are affected by diverse pathological factors such as cell differentiation, the amount of tissue stroma, the infiltration pattern, and the presence or absence of ulceration. Gastric cancers may thus show diverse enhancement patterns on contrast-enhanced MDCT. Takao et al. [21] reported that gastric cancers composed of marked fibrous tissue stroma showed gradual enhancement on triphasic spiral CT, and the entire tumour was depicted most clearly in the equilibrium phase and was underestimated for tumour invasion if only the arterial or parenchymal phases were obtained.

EGC-Us contain varying degrees of fibrous tissue associated with ulceration, similar to benign gastric ulcers. Chen et al. [1] evaluated the use of monophasic MDCT with virtual gastroscopy and multiplanar reconstruction (MPR) for differentiating malignant gastric tumours from benign gastric ulcers. They reported that most of the gastric cancers had significantly enhanced tumour parts in the portal venous phase, whereas the benign gastric ulcers exhibited no significant enhancement on contrast-enhanced MPR images. Our present findings revealed that most of the EGC-Us enhancement

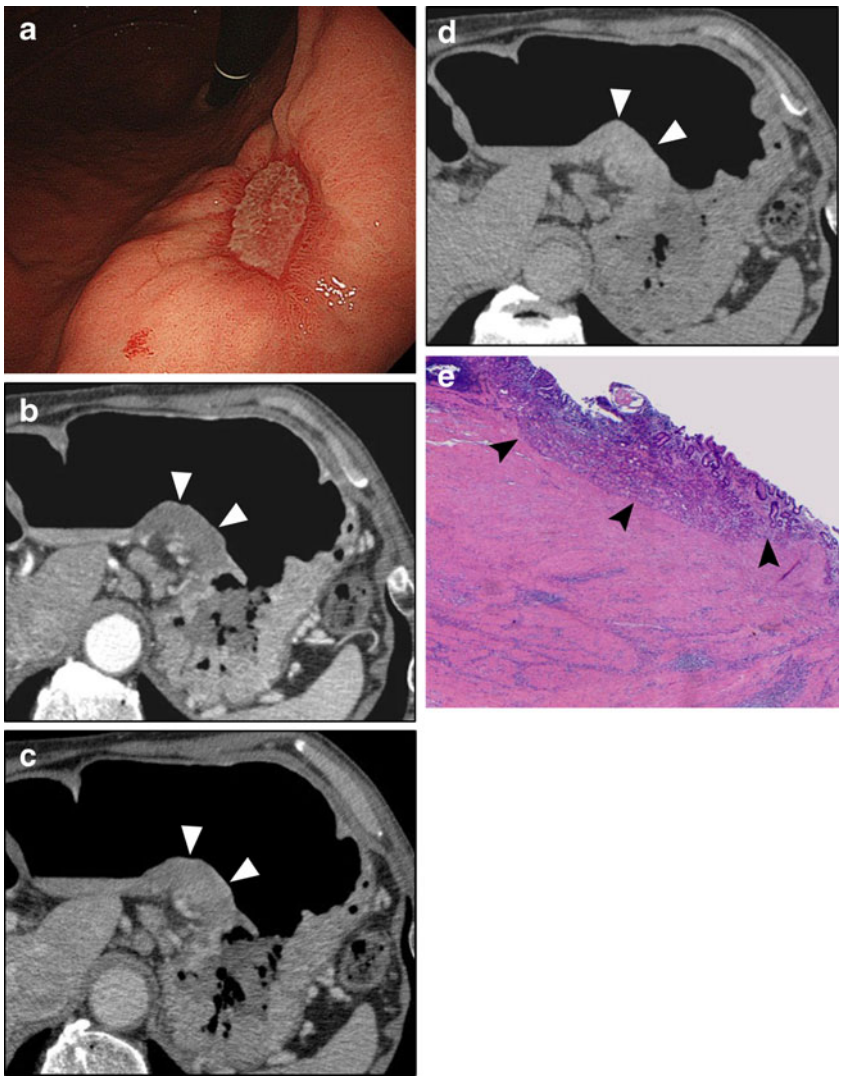

Fig. 2 Early gastric cancer with ulceration (EGC-U) (submucosal tumour invasion with Ul-III ulcer) in a 75-year-old man. (**a**) Gastroscopy showed an ulcerative lesion of the lesser curvature of the gastric angle. (**b**–**d**) Multidetector CT showed wall thickening of the lesser curvature of the stomach (arrowheads). According to both readers, the attenuation values were 52.3 and 61.0 HU in the arterial phase (**b**), 83.2 and 85.3 HU in the portal phase (**c**) and 100.7 and 90.0 in the delayed phase (**d**). (**e**) A photomicrograph (original magnification×100) showed infiltration of adenocarcinoma cells confined to the mucosa (arrowheads) and dense fibrosis within the submucosal and the muscle layer (below arrowheads)

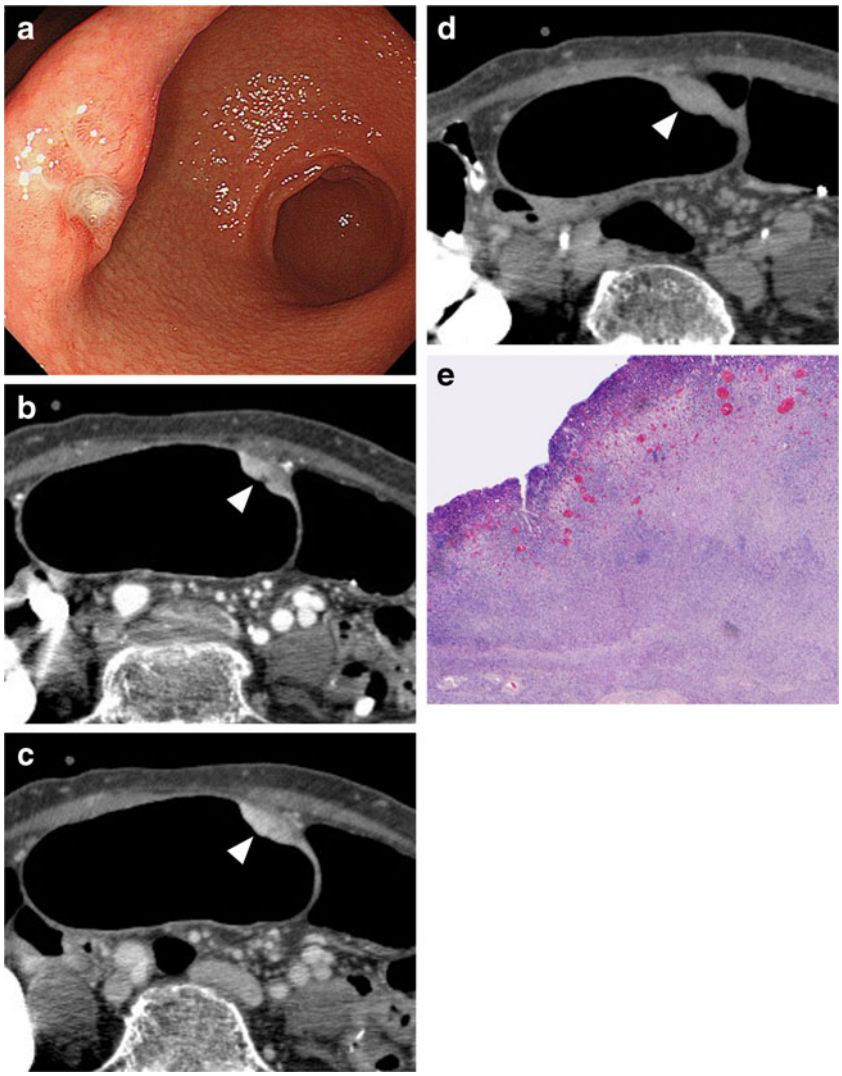

Fig. 3 Advanced gastric cancer (AGC) (serosal tumour invasion) in a 48-year-old woman. (**a**) Gastroscopy showed an ulcerative lesion of the lesser curvature of the gastric angle. (**b**–**d**) Multidetector CT showed thickening of the anterior wall of the stomach (arrowhead). According to both readers, the attenuation values were 153.9 and 173.0 HU in the arterial phase (**b**), 179.2 and 206.2 HU in the portal phase (**c**) and 135.7 and 146.3 in the delayed phase (**d**). (**e**) A photomicrograph (original magnification×100) shows infiltration of adenocarcinoma cells into the serosal layer

peaked in the delayed phase, with significant difference. This enhancement pattern may be influenced by a fibrous component associated with ulceration within the tumour.

In the CT image analyses, we observed that diagnostic performance using the ROC method for differentiating the EGC-Us from the AGCs showed high accuracy in both the arterial phase (82.5 % and 85.0 %) and the portal phase (92.5 % and 90.0 %). It is sometimes difficult to differentiate EGC-Us from AGCs based on the endoscopic or fluoroscopic appearance, because EGC-Us from AGCs can have a similar endoscopic appearance associated with ulceration [4]. Our present findings showed that the endoscopic evaluation had lower accuracy values (70.0 % and 72.5 %) in differentiating EGC-Us from AGCs.

EUS is the first-choice imaging modality for determining the depth of gastric cancer invasion, and its tumour stage accuracy has been reported to be 80–90 % [22, 23]. However, the diagnostic performance of EUS in diagnosing the invasion depth of EGC-Us decreases to an accuracy rate of 63–70 % due to fibrous tissue stroma within the tumour [6, 7, 24]. In contrast, a sectional image examination such as CT can evaluate gastric cancers with or without ulcerative change. Hwang et al. [11] reported that the diagnostic accuracies of MDCT for the staging of gastric cancers with and without ulcerative changes were not significantly different [11]. The accurate diagnosis of the invasion depth is crucial for deciding on the treatment strategy for gastric cancers.

Laparoscopic surgery [25] and endoscopic submucosal dissection [26] for early gastric cancer have been shown to improve patients' quality of life. The use of these procedures requires a more accurate preoperative analysis of the depth of invasion [9]. Our present findings demonstrate that multiphasic dynamic MDCT was useful in differentiating EGC-Us and AGCs via a comparison of their attenuation values in the arterial and portal phases. There was no significant difference in attenuation values between the EGC-Us and AGCs in the delayed phase. However, most of the EGC-Us enhancement peaked in the delayed phase, probably due to fibrous tissue

stroma within the tumour. It may be useful to focus on the peak enhancement for a more accurate differentiation of EGC-Us and AGCs.

Our study has several limitations. First, the study was retrospective with a small patient population. Second, we have no data of unenhanced CT in this series. Greater accuracy may be achieved if we analyse the enhancement pattern of gastric cancer using unenhanced CT. Third, all of the cases in our series were resectable gastric cancers. It is unclear whether our results are applicable to unresectable gastric cancers. Even with these potential limitations, our findings suggest that the attenuation value measurements help differentiate EGC-Us from AGCs.

Conclusions

The EGC-Us had significantly lower attenuation values compared to the AGCs in both the arterial and portal phases. The difference in enhancement pattern could be a key diagnostic feature for differentiating EGC-Us from AGCs on multiphasic dynamic MDCT when endoscopy or endosonography results are not able to be confirmed.

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References

1. Chen CY, Wu DC, Kuo YT, Lee CH, Jaw TS, Kang WY et al (2008) MDCT for differentiation of category T1 and T2 malignant lesions from benign gastric ulcers. Am J Roentgenol 190:1505–1511
2. Haukland HH, Johnson JA, Eide JT (1981) Carcinoma diagnosed in excised gastric ulcers. Acta Chir Scand 147:439–443
3. Shimizu S, Tada M, Kawai K (1995) Early gastric cancer: its surveillance and natural course. Endoscopy 27:27–31
4. Kitamura K, Yamaguchi T, Nishida S, Yamamoto K, Okamoto K, Taniguchi H et al (1997) Early gastric cancer mimicking advanced gastric cancer. Br J Cancer 75:1769–1773
5. Kim JP, Lee JH, Kim SJ, Yu HJ, Yang HK (1998) Clinicopathologic characteristics and prognostic factors in 10 783 patients with gastric cancer. Gastric Cancer 1:125–133
6. Kim GH, Park do Y, Kida M, Kim DH, Jeon TY, Kang HJ et al (2010) Accuracy of high-frequency catheter-based endoscopic ultrasonography according to the indications for endoscopic treatment of early gastric cancer. J Gastroenterol Hepatol 25:506–511
7. Choi J, Kim SG, Im JP, Kim JS, Jung HC, Song IS (2010) Is endoscopic ultrasonography indispensable in patients with early gastric cancer prior to endoscopic resection? Surg Endosc 24:3177–3185
8. Kim JH, Eun HW, Choi JH, Hong SS, Kang W, Auh YH (2007) Diagnostic performance of virtual gastroscopy using MDCT in early gastric cancer compared with 2D axial CT: focusing on interobserver variation. Am J Roentgenol 189:299–305
9. Furukawa K, Miyahara R, Itoh A, Ohmiya N, Hirooka Y, Mori K et al (2011) Diagnosis of the invasion depth of gastric cancer using MDCT with virtual gastroscopy: comparison with staging with endoscopic ultrasound. Am J Roentgenol 197:867–875
10. Habermann CR, Weiss F, Riecken R, Honarpisheh H, Bohnacker S, Staedtler C et al (2004) Preoperative staging of gastric adenocarcinoma: comparison of helical CT and endoscopic US. Radiology 230:465–471
11. Hwang SW, Lee DH, Lee SH, Park YS, Hwang JH, Kim JW et al (2010) Preoperative staging of gastric cancer by endoscopic ultrasonography and multidetector-row computed tomography. J Gastroenterol Hepatol 25:512–518
12. Japanese Gastric Cancer A (2011) Japanese classification of gastric carcinoma: 3rd English edition. Gastric Cancer 14:101–112
13. Niwa Y, Nakazawa S, Tsukamoto Y, Goto H, Hase S, Ohashi S et al (1991) A new method for evaluating gastric ulcer healing by endoscopic ultrasonography. Scand J Gastroenterol 26:457–464
14. Ulla M, Cavadas D, Munoz I, Beskow A, Seehaus A, Garcia-Monaco R (2010) Esophageal cancer: pneumo-64-MDCT. Abdom Imaging 35:383–389
15. Kim HJ, Kim AY, Oh ST, Kim JS, Kim KW, Kim PN et al (2005) Gastric cancer staging at multi-detector row CT gastrography: comparison of transverse and volumetric CT scanning. Radiology 236:879–885
16. Efsen F, Fischerman K (1974) Angiography in gastric tumours. Acta Radiol Diagn 15:193–197
17. Shibata S, Iwasaki N (1970) Angiographic findings in diseases of the stomach. Am J Roentgenol Radium Ther Nucl Med 110:322–331
18. Minami M, Kawauchi N, Itai Y, Niki T, Sasaki Y (1992) Gastric tumors: radiologic-pathologic correlation and accuracy of T staging with dynamic CT. Radiology 185:173–178
19. Cho JS, Kim JK, Rho SM, Lee HY, Jeong HY, Lee CS (1994) Preoperative assessment of gastric carcinoma: value of two-phase dynamic CT with mechanical iv. injection of contrast material. Am J Roentgenol 163:69–75
20. Kim HS, Han HY, Choi JA, Park CM, Cha IH, Chung KB et al (2001) Preoperative evaluation of gastric cancer: value of spiral CT during gastric arteriography (CTGA). Abdom Imaging 26:123–130
21. Takao M, Fukuda T, Iwanaga S, Hayashi K, Kusano H, Okudaira S (1998) Gastric cancer: evaluation of triphasic spiral CT and radiologic-pathologic correlation. J Comput Assist Tomogr 22:288–294
22. Kwee RM, Kwee TC (2008) The accuracy of endoscopic ultrasonography in differentiating mucosal from deeper gastric cancer. Am J Gastroenterol 03:1801–1809
23. Puli SR, Batapati Krishna Reddy J, Bechtold ML, Antillon MR, Ibdah JA (2008) How good is endoscopic ultrasound for TNM staging of gastric cancers? A meta-analysis and systematic review. World J Gastroenterol 14:4011–4019
24. Akashi K, Yanai H, Nishikawa J, Satake M, Fukagawa Y, Okamoto T et al (2006) Ulcerous change decreases the accuracy of endoscopic ultrasonography diagnosis for the invasive depth of early gastric cancer. Int J Gastrointest Cancer 37:133–138
25. Kitano S, Shiraishi N (2004) Current status of laparoscopic gastrectomy for cancer in Japan. Surg Endosc 18:182–185
26. Gotoda T, Yamamoto H, Soetikno RM (2006) Endoscopic submucosal dissection of early gastric cancer. J Gastroenterol 41:929–942