Comparison between blinded and partially blinded detection of gastric cancer with multidetector CT using surgery and endoscopic submucosal dissection as reference standards

H J KIM, MD, D H LEE, MD and Y T KO, MD

Department of Radiology, Kyung Hee University Medical Center, 1, Hoegi-dong, Dongdaemun-gu, Seoul 130-702, Korea

ABSTRACT. The aim of this study is to compare blinded with partially blinded detection of gastric cancer with multidetector (MD) CT by using surgery and endoscopic submucosal dissection (ESD) as reference standards. 44 patients with gastric cancer underwent MDCT with air as an oral contrast agent. Surgery was performed on 37 patients, ESD on six and surgery after ESD on one. To provide comparison cases of blinded evaluation, 38 MDCT examinations were added for cases where no focal gastric lesion was seen on endoscopy. Two radiologists, blinded to the presence, number and location of the tumours, evaluated axial and axial plus multiplanar reformation (MPR) images of 82 MDCT examinations with or without gastric cancer. For partially blinded evaluation, the same radiologists, blinded to the location and number of tumours, evaluated axial and axial plus MPR images of 44 MDCT examinations of gastric cancer. Differences in assessment were resolved by consensus. 45 gastric cancers were found in surgical and ESD specimens. Detection rates of gastric cancer from axial and axial plus MPR images during blinded evaluation and from axial and axial plus MPR images during partially blinded evaluation were 62% (28/45), 64% (29/45), 64% (29/45) and 71% (32/45), respectively. There was no statistical significance for the comparison between blinded and partially blinded detection rates of gastric cancer. The detection rate of gastric cancer with MDCT during blinded evaluation showed no specific difference compared with the detection rate of gastric cancer with MDCT during partially blinded evaluation.

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Gastric cancer is one of the most frequent causes of cancer-related death worldwide [1]. Patients with advanced gastric cancer have 5-year survival rates of less than 30% [2]. However, patients with early gastric cancer have 5-year survival rates of more than 85% [3, 4]. Therefore, early detection of gastric cancer is essential for the improvement of patient survival and for the reduction of the overall use of medical resources. Although the use of endoscopy and a double-contrast barium study has a significant role in the detection of gastric cancer, the depth of tumour invasion and the presence or absence of metastasis cannot be determined by the use of these modalities. Multidetector CT (MDCT) is usually performed for pre-operative staging work-up of patients with gastric cancer. Accurate evaluation of the location and local extent of the gastric cancer (T stage) is important in the choice of the optimal therapeutic approach. However, if gastric cancer cannot be detected on MDCT, the modality cannot provide the information about the location and T stage of gastric cancer. Thus, lesion detection on MDCT is a prerequisite for gastric cancer staging on MDCT [5].

Currently, some early gastric cancers may be treated with laparoscopic gastrectomy or endoscopic submucosal

dissection (ESD) without laparotomy [6, 7]. However, most studies on gastric cancer have confined the study population to patients who have received a laparotomy [5, 8–11]. This strict confinement of the study population may result in an overestimation of the detection rate of gastric cancer. Most results for the detection rate of gastric cancer have another limitation as the study population is composed only of patients with gastric cancer [5, 8–12], and patients without gastric cancer are usually not included in the study population. Hence, the accuracy of detection of gastric cancer with MDCT may be overestimated. The purpose of this study is to evaluate the accuracy of blinded and partially blinded detection of gastric cancer with MDCT by the use of surgery and ESD as reference standards.

Methods and materials

Patients

This study was a single-institution retrospective study. The study was approved by the institutional review board, which waived the requirement for informed consent. A search of the picture archiving and communication system (PACS) database over a 12-month period (June 2006 to May 2007) yielded 126 patients who had undergone MDCT with air as an oral contrast agent for

Address correspondence to: Hyoungh Jung Kim, MD, Department of Radiology, Kyung Hee University Medical Center, 1, Hoegi-dong, Dongdaemun-gu, Seoul 130-702, Korea. E-mail: radhjkim@khu.ac.kr

gastric distension. The study enrolment and demographic data are summarised in Figure 1. The final study population consisted of 44 patients with gastric cancer and 38 patients without focal gastric lesions. The mean interval between endoscopy and CT was 1.7 days (range 0–10 days). All 44 patients with gastric cancer underwent surgery ($n=37$), ESD ($n=6$) or surgery after ESD ($n=1$). The mean interval between MDCT examination and surgery or ESD was 6.4 days (range 0–25 days). All 38 patients without focal gastric lesions were referred for a CT examination because of vague abdominal symptoms, including epigastric pain or discomfort ($n=26$), dyspepsia ($n=8$), nausea ($n=2$) and weight loss ($n=2$).

CT protocol

All 82 patients underwent MDCT after overnight fasting to empty the stomach. The key CT protocol and image reconstruction are summarised in Table 1.

Image analysis

Two radiologists (with 9 and 25 years' experience) evaluated the images on PACS monitors. Disagreement in the interpretation was resolved by consensus after discussion. Two observers were blinded to the location, number and size of tumours. The image analysis consisted of four separate sessions. Two sessions were performed for blinded evaluation and the other two sessions were performed for partially blinded evaluation. For the blinded evaluation, CT images of 82 patients, consisting of 44 patients with gastric cancer and 38 patients without a focal gastric lesion, were randomly presented. First, 5-mm thickness axial images were evaluated without multiplanar reformation (MPR) images. Second, 5-mm thickness axial plus MPR images were evaluated. For the partially blinded evaluation, CT images of 44 patients with gastric cancer were randomly

presented. During the third session, 5-mm thickness axial images were evaluated without MPR images. During the fourth session, 5-mm thickness axial plus MPR images were evaluated. To diminish learning effects, the interval between each evaluation session was at least three weeks.

A lesion was determined to be cancerous when the gastric wall showed focal thickening of at least 6 mm or greater or when focal enhancement was seen in the gastric wall (Figure 2). For comparison with surgical and endoscopic results, the tumour location was recorded according to the Japanese classification of early gastric cancer [13]. The stomach was divided into three portions—the upper, middle and lower parts. If more than one portion was involved, the portion in which the bulk of the tumour was located was recorded. Entire gastric involvement was also recorded. The cross-sectional circumference of the stomach was divided into four equal parts—the lesser and greater curvature, and the anterior and posterior walls. Circumferential involvement was also recorded.

Reference standards

A radiologist, who defined the study population and did not participate in the image analysis, determined the reference standards. In 38 patients who underwent surgery, surgical and pathological reports were reviewed to determine the tumour location, depth of invasion and morphological subtype. In six patients who underwent only ESD, endoscopic reports, endoscopic images and pathological reports were reviewed to determine the tumour location, depth of invasion and the morphological subtype. An experienced endoscopist participated in the review of the endoscopic reports and images. The location of the tumour was recorded according to the same criteria of image analysis. The morphological subtype of gastric cancer was classified according to the Japanese classification of early gastric cancer and the

Figure 1. Flow chart of study enrolment and demographic data. GIST, gastrointestinal stromal tumour; FU, follow-up.

Table 1. Multidetector CT acquisition

Characteristics	16-detector row CT scanner ^a	64-detector row CT scanner ^b
Preparation ^c	6 g of effervescent granules ^d with 10 ml of tap water	
Scan parameters		
Section collimation	1.25 mm × 16 mm	0.625 mm × 64 mm
Table speed	20 mm/rotation	40 mm/rotation
Rotation time	0.5 s	0.75 s
Contrast agent	100 ml of iopromide ^e	
Contrast injection	Power injector; flow rate 3 ml s ⁻¹	
Scan delay	70 s after the initiation of contrast material injection	
Scan coverage	Dome of the right hemidiaphragm – anus	
Reconstruction		
Axial		
Intersection distance	5 mm	5 mm
Section width	5 mm	5 mm
MPR		
Intersection distance	2 mm	2 mm
Section width	2 mm	2 mm

MPR, multiplanar reformation.

^aLightSpeed pro; GE Medical Systems, Milwaukee, WI.^bBrilliance 64; Philips Medical Systems, Cleveland, OH.^cSmooth muscle relaxant was not administered. Additional effervescent granules were given if the stomach was not adequately distended on scanogram.^dTop; Taejoon Pharmaceutical, Gyeonggido, Korea.^eUltravist 370; Schering, Berlin, Germany.

(a)

(b)

Figure 2. Early gastric cancer Type IIb in a 72-year-old woman. Axial CT (a) and sagittal reformation (b) images show focal wall thickening and enhancement in antrum, posterior wall (arrows). This lesion was detected on both axial and axial plus multiplanar reformation images and during both blinded and partially blinded evaluation.

Borrmann classification of advanced gastric cancer [13, 14]. Early gastric cancers were classified as follows: Type I, protruded; Type IIa, superficial elevated; Type IIb, flat; Type IIc, superficial depressed; Type III, excavated. Advanced gastric cancers were classified as follows: Type I, polypoid; Type II, fungating; Type III, ulcerated; Type IV, diffuse infiltrative. T staging was based on the pathological TNM (tumour node metastases) staging according to the American Joint Committee on Cancer and the International Union Against Cancer [15] (Table 2). Additionally, pT1 tumours were subdivided into tumours localised in the mucosa or submucosa.

After completion of the image analysis and determination of the reference standards, a conference was held between the two radiologists participating in the image analysis and the radiologist determining the reference standards. If the tumour location on CT was the same location as a reference standard, it was determined as true detection. If the tumour location on CT was at a different location from a reference standard, it was determined as false detection. If observers did not find the tumour on CT images, it was determined as non-detection. Additional evaluation was also made to determine the cause of false detection by the use of axial plus MPR images and reference standards.

Statistical analysis

The true detection rate, false detection rate and non-detection rate during four different sessions were calculated. The differences in these rates between the axial images and axial plus MPR images and between the blinded and partially blinded evaluation were assessed by using the McNemar exact test. A *p*-value less than 0.05 was considered to indicate statistical significance. Statistical analysis was conducted with statistical software (SPSS for Windows, version 11.0 for Windows; SPSS, Chicago, IL).

Results

T staging, morphology and location of gastric cancers on reference standards

One patient had two gastric cancers. Therefore, 45 gastric cancers were present in 44 patients. Among the 45 tumours, 24 tumours (53%) were staged as pT1, 16 tumours (36%) were staged as pT2, 3 tumours (7%) were staged as pT3 and 2 tumours (4%) were staged as pT4. Among 24 pT1 tumours, 11 tumours (11/45, 24%) were confined to the mucosa and 13 tumours (13/45, 29%) were confined to the submucosa. Morphologically, 24 early gastric cancers were classified as the following: 2 Type I, 1 Type IIa, 6 Type IIb, 13 Type IIc and 2 Type III according to the Japanese classification of early gastric cancer. 21 advanced gastric cancers were classified as the following: 2 Type I, 3 Type II, 11 Type III and 5 Type IV according to the Borrmann classification. 45 gastric cancers were located at the upper (*n*=5), middle (*n*=17) and lower (*n*=21) parts of the stomach or with entire gastric involvement (*n*=2). On the cross-sectional

Table 2. Pathological T staging developed by the American Joint Committee on Cancer and the International Union Against Cancer in 2002

Stage	Description
pT1	Tumour confined to the mucosa or submucosal layer
pT2	Tumour extending into muscularis propria or subserosa
pT3	Tumour extending through the serosa without involving contiguous structures
pT4	Tumour extending to contiguous structures

circumference of the stomach, 45 gastric cancers were located at the lesser curvature (*n*=14), greater curvature (*n*=8), anterior wall (*n*=7), posterior wall (*n*=11) or showed circumferential involvement (*n*=5).

Detection of gastric cancers

The true detection rates of gastric cancer using axial and axial plus MPR images on blinded and partially blinded evaluation according to the T stage are summarised in Table 3 (Figure 3). The true detection, false detection and non-detection rates of gastric cancer using axial and axial plus MPR images on blinded and partially blinded evaluation are summarised in Table 4.

False and non-detection of gastric cancers

Thirteen early gastric cancers were non-detected or false detected during partially blinded evaluation using axial plus MPR images. These 13 early gastric cancers were composed of mucosal cancers (*n*=10) and submucosal cancers (*n*=3). Morphologically, there were 2 Type IIb lesions and 11 Type IIc lesions. These tumours were located at the upper (*n*=1), middle (*n*=5) and lower (*n*=7) parts of the stomach. On the cross-sectional circumference of the stomach, these tumours were located at the lesser curvature (*n*=5), greater curvature (*n*=3), anterior wall (*n*=3) and posterior wall (*n*=2). The detection rate of mucosal cancer was very low (9%, 1/11) compared with the detection rate of submucosal cancer (85%, 11/13).

The false detection rate of gastric cancer was low (7% using axial images and 7% using axial plus MPR images) from the blinded evaluation compared with the false detection rate of gastric cancer from the partially blinded evaluation (13% using axial images and 11% using axial plus MPR images). The low false detection rate of gastric cancers from the blinded evaluation was accompanied by a relatively high non-detection rate for the blinded evaluation, which was 31% using axial images and 29% using axial plus MPR images. In comparison, the non-detection rate for the partially blinded evaluation was 22% using axial images and 18% using axial plus MPR images.

False detection occurred in five locations during the partially blinded evaluation using axial plus MPR images. These false detections occurred at the middle (*n*=2) and lower (*n*=3) part of the stomach. On the cross-sectional circumference of the stomach, these tumours were located at the greater curvature (*n*=2), anterior wall (*n*=1) and posterior wall (*n*=2). A retrospective review

Table 3. True detection rates of gastric cancer using axial and axial plus multiplanar reformation (MPR) images on blinded and partially blinded evaluation according to the T stage

	True detection of gastric cancer			
	pT1 (n=24)	pT2 (n=16)	pT3 (n=3)	pT4 (n=2)
Blinded				
Axial	7 (29)	16	3	2
Axial + MPR	8 (33)	16	3	2
Partially blinded				
Axial	8 (33)	16	3	2
Axial + MPR	11 (46)	16	3	2

Numbers in parentheses are percentages.

of these cases showed that the observers might have confused a giant fold in the greater curvature or anterior wall of the stomach with a tumour ($n=3$) (Figure 4) or confused an overshooting artefact by air at the posterior wall with a focal enhancement of the gastric wall with a tumour ($n=2$). False detection also occurred in three patients without focal gastric lesions (8%, 3/38). All false detections occurred in the lower part of the stomach, and two occurred in the greater curvature side and one occurred in the posterior wall. A retrospective review of these cases showed that the observers might have confused a prominent fold in the greater curvature of the stomach with a tumour ($n=2$) or confused an overshooting artefact by air at the posterior wall with a focal enhancement of the gastric wall with a tumour ($n=1$) (Figure 5).

Discussion

In this study, MDCT demonstrated a poor detection rate of 29–46% for early gastric cancers according to each image analysis method employed, although MDCT showed an excellent detection rate of 100% for advanced gastric cancers. According to previous reports where investigators used a single-detector helical CT scanner, the detection rate of early gastric cancers on two-dimensional axial CT was low, between 26% and 56%

[16–18]. Our detection rate for early gastric cancers is similar to the results obtained by the use of a single-detector helical CT [16–18]. Recently published studies have reported high detection rates for early gastric cancers of between 73% and 90% [5, 8–10, 12]. However, Shimizu et al [19] reported a low detection rate of 41% for early gastric cancers for a study using 4-channel MDCT. These wide variations in the detection rate of early gastric cancers may cause controversy about the “true detectability” of early gastric cancers with MDCT. In daily clinical practice, it is not unusual to fail to detect gastric cancers that were histologically verified on endoscopic biopsies.

The detection rate of early gastric cancer might be influenced by many factors including the study population, MDCT examination technique, the image analysis method and the MDCT scanner. First, the study population may have a direct influence over the detection rate of early gastric cancer. If the study population was confined to patients receiving a laparotomy, the detection rate of early gastric cancer was very high, ranging from 88% to 96% [5, 8–10]. If the study population included patients receiving a laparotomy or laparoscopic gastrectomy, the detection rate of early gastric cancer was slightly decreased, ranging from 73% to 76% [12]. If the study population included all gastric cancer patients receiving a laparotomy, laparoscopic gastrectomy or ESD, the detection rate of early gastric

Figure 3. Early gastric cancer Type IIb in a 58-year-old man. (a) Axial CT image does not show abnormal wall thickening. On axial CT image, the lesion was not detected during blinded or partially blinded evaluation. (b) Coronal reformation image shows focal wall thickening and enhancement in the gastric angle (arrow), lesser curvature side. On axial plus multiplanar reformation images, the lesion was detected during both blinded and partially blinded evaluation.

Table 4. True detection, false detection and non-detection of 45 gastric cancers on blinded and partially blinded evaluation

	Blinded		Partially blinded	
	Axial ^a	Axial + MPR ^b	Axial ^c	Axial + MPR ^d
True detection	28/45 (62)	29/45 (64)	29/45 (64)	32/45 (71)
False detection	3/45 (7)	3/45 (7)	6/45 (13)	5/45 (11)
Non-detection	14/45 (31)	13/45 (29)	10/45 (22)	8/45 (18)

Numbers in parentheses are percentages. MPR, multiplanar reformation.

p -value between a and $c=0.262$; p -value between b and $d=0.172$; p -value between a and $b=0.801$; p -value between c and $d=0.262$.

cancer was markedly decreased, as low as 41% [19]. In a gastric cancer study, the strict confinement of the study population may increase the detection rate of gastric cancer and vice versa. The study population of gastric cancer patients may also change with time. Screening programmes for the asymptomatic population for gastric cancer [20] and advances in endoscopic techniques [21] increase the proportion of early gastric cancers among all those that might not have been detected previously. In our clinical practice, the number of small early gastric cancers that are barely detected, even on endoscopy, is

increasing. Our study population consisted of patients with gastric cancers treated by a laparotomy or ESD, so this less strict confinement of the study population might lower the detection rate of early gastric cancer.

Second, the MDCT examination technique is also another factor affecting the detection rate of early gastric cancer. MPR images can detect more gastric cancers than axial CT images [5, 8, 10]. CT gastroscopy can detect additional cancers that are not detected on MPR images [5, 8]. In our study, we could detect more early gastric cancers on axial plus MPR images than on axial images

(a)

(b)

(c)

Figure 4. Early gastric cancer Type IIc in a 55-year-old man. Axial CT (a) and coronal reformation (b) images show focal wall thickening in the body, greater curvature side (arrows). This focal wall thickening was interpreted as a gastric cancer during both blinded and partially blinded evaluation. (c) Endoscopy shows a Type IIc lesion in the body, posterior wall (arrowheads). False detection was made on both axial and axial plus multiplanar reformation images and during both blinded and partially blinded evaluation.

Figure 5. A 71-year-old man without a focal gastric lesion. Axial CT (a) and sagittal reformation (b) images show focal wall enhancement in antrum, posterior wall (arrows). This focal wall enhancement was interpreted as a gastric cancer on both blinded and partially blinded evaluation. (c) Endoscopy shows no evidence of gastric cancer in the antrum. False detection was made on both axial and axial plus multiplanar reformation images and during both blinded and partially blinded evaluation.

alone, although this observation did not have statistical significance. The third factor that may influence the detection rate of early gastric cancers is the evaluation method. Recently published studies had the basic limitation that the study population included only patients with histologically confirmed gastric cancer, except in one report [22]. The knowledge that all CT images had a gastric cancer might increase the detection rate of early gastric cancer. Finally, the MDCT scanner itself may influence the detection rate of gastric cancer, because a 64-channel MDCT may shorten the scan time in comparison with a four-channel MDCT. However, the difference in the detection rate of early gastric cancers between the use of a 64-channel MDCT and four-channel MDCT under a similar study population is not high [5, 8, 9], as the four-channel MDCT can also offer a near-isotropic image of the stomach and allows high-quality MPR images to be obtained.

In this study, we tried to assess the accuracy of MDCT in the detection of gastric cancers. For patients with advanced gastric cancers, the gastric cancer T stage (pT2, pT3 or pT4) did not influence the tumour detection rate. The examination technique, such as axial imaging *vs*

axial plus MPR imaging, also did not influence the detection rate of advanced gastric cancers. Finally, the analysis method, such as a blinded or partially blinded evaluation, also did not influence the detection rate. Therefore, detection of advanced gastric cancers by the use of MDCT is a reliable examination technique and analysis method, regardless of the T stage.

All non-detected (18%, 8/45) or falsely detected (11%, 5/45) tumours on evaluation using axial plus MPR images under partially blinded evaluation were early gastric cancers. Mucosal cancer was detected in 9% (1/11) and submucosal cancer in 77% (10/13) of the cases. Axial plus MPR images were able to detect more tumours than axial images alone; however, their use still had limitations, such as in imaging mucosal cancer in the absence of a thickened gastric wall Type IIc (85%, 11/13) early gastric cancers, were more common than Type IIb (33%, 2/6) among the non-detected or falsely detected tumours on axial plus MPR images during the partially blinded evaluation. In some reports that had a strict study population and high detection rates of early gastric cancers, the Type IIb lesion was the only or most common morphological type that was not detected on CT [5, 8, 9].

However, in other reports that had a less strict study population and a relatively low detection rate of early gastric cancers, the Type IIc lesion was the most common morphological type that was not detected on CT [12, 22]. In our study, the depth of tumour invasion might have played an important role in tumour detection. CT gastroscopy can provide a similar image to that of endoscopy or a double-contrast barium study, and allows additional detection for the evaluation of gastric cancers. However, it still has a limitation in detecting shallow ulceration of early gastric cancer [12, 22].

False detection of gastric cancers was more common on the partially blinded evaluation than on the blinded evaluation, although there was no statistical significance. Kim et al [22] had reported that discordance between virtual gastroscopy-detected early gastric cancer and endoscopically detected early gastric cancer ranged from 4% to 10% on blinded evaluation. In our study, a giant fold in the greater curvature or anterior wall of the stomach ($n=3$) or overshooting artefact caused by air at the posterior wall ($n=2$) were misinterpreted as a tumour on the partially blinded evaluation using axial plus MPR images. On some reports, a giant fold in the greater curvature side was mentioned as a cause of false detection [11, 22]; however, many reports do not mention the presence or absence of false detection of gastric cancers [5, 9, 10, 12, 19]. An overshooting artefact due to intraluminal air may cause false detection [8, 23]. Some studies of gastric cancer have used water instead of gas for gastric distension [11, 19]. Although many recent studies on gastric cancer have used gas for gastric distension [5, 9, 10, 12, 19], reports describing an overshooting artefact were difficult to locate. If we add CT gastroscopy to the image analysis, some of the overshooting artefacts on axial plus MPR images might be interpreted as non-detected lesions rather than falsely detected lesions. Radiologists should be careful not to identify an artefact as a tumour, as some early gastric cancers may not be visible on MDCT and false tumour detection may cause confusion in the management of gastric cancers.

There are several limitations to this study. First, we excluded benign gastric ulcers, adenomas or high-grade dysplasia from the population. These benign or pre-cancerous lesions might mimic gastric cancer and lower the accuracy of MDCT in the detection of gastric cancer. There was no statistically significant difference between blinded and partially blinded evaluation in the detection rate of gastric cancer; however, these results might also be influenced by the excluded cases from the study population. Second, we did not perform CT gastroscopy. On previous reports, CT gastroscopy could detect an additional 10–15% of early gastric cancers that were not detected on MPR images [5, 8]. If we had used CT gastroscopy in addition to the MPR images, the detection rate of gastric cancer might have increased. This study was a retrospective study, so we could not use CT gastroscopy in addition to the MPR images. The third limitation of this study was that we did not obtain the gastric mucosal phase. The layered pattern of the normal gastric wall and early gastric cancer can be depicted clearly in the gastric mucosal phase [24, 25]. It is useful for identifying the enhancement pattern of early gastric cancer [24] and for determining the depth of tumour invasion [25]. It also may be useful for tumour detection,

especially for those tumours without obvious gastric wall thickening [8]. However, there is no well-designed comparative study on the detection rate of gastric cancer between the gastric mucosal phase and the portal venous phase. Additional radiation is a limitation of the gastric mucosal phase. Fourth, when we performed the blinded evaluation, observers already knew that some of the CT images might be obtained from patients with gastric cancer. Thus, this study was not a completely blinded evaluation. However, it is practically impossible to perform a completely blinded evaluation in the radiological study of the gastric cancer.

In conclusion, MDCT can accurately detect advanced gastric cancers. However, MDCT still has limitations in detecting gastric cancers confined within the mucosa or submucosa. The detection rate of gastric cancer with MDCT under a blinded evaluation showed no statistical difference in comparison with the detection rate under a partially blinded evaluation.

References

1. Devesa SS, Blot WJ, Fraumeni JF Jr. Changing patterns in the incidence of esophageal and gastric carcinoma in the United States. *Cancer* 1998;83:2049–53.
2. Martin RC 2nd, Jaques DP, Brennan MF, Karpeh M. Extended local resection for advanced gastric cancer: increased survival versus increased morbidity. *Ann Surg* 2002;236:159–65.
3. Nitti D, Marchet A, Mammano E, Ambrosi A, Belluco C, Mencarelli R, et al. Extended lymphadenectomy (D2) in patients with early gastric cancer. *Eur J Surg Oncol* 2005;31:875–81.
4. Carter KJ, Schaffer HA, Ritchie WP Jr. Early gastric cancer. *Ann Surg* 1984;199:604–9.
5. 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.
6. Gotoda T, Yamamoto H, Soetikno RM. Endoscopic submucosal dissection of early gastric cancer. *J Gastroenterol* 2006;41:929–42.
7. Lee SI, Choi YS, Park DJ, Kim HH, Yang HK, Kim MC. Comparative study of laparoscopy-assisted distal gastrectomy and open distal gastrectomy. *J Am Coll Surg* 2006;202:874–80.
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.
9. Yang DM, Kim HC, Jin W, Ryu CW, Kang JH, Park CH, et al. 64 multidetector-row computed tomography for preoperative evaluation of gastric cancer: histological correlation. *J Comput Assist Tomogr* 2007;31:98–103.
10. Hur J, Park MS, Lee JH, Lim JS, Yu JS, Hong YJ, et al. Diagnostic accuracy of multidetector row computed tomography in T- and N staging of gastric cancer with histopathologic correlation. *J Comput Assist Tomogr* 2006;30:372–7.
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.
12. Shin KS, Kim SH, Han JK, Lee JM, Lee HJ, Yang HK, et al. Three-dimensional MDCT gastrography compared with axial CT for the detection of early gastric cancer. *J Comput Assist Tomogr* 2007;31:741–9.
13. Japanese Gastric Cancer Association. Japanese classification of gastric carcinoma, 2nd English edition. *Gastric Cancer* 1998;1:10–24.

14. Borrmann R. Geshwulste des magens und duodenums. In: Henke F, Lubarsch O, editors. *Handbuch der Speziellen Pathologischen Anatomie und Histologie*. Berlin, Germany: Springer-Verlag, 1926:865.
15. Greene FL, Page DL, Fleming ID, Fritz AG, Balch CM, Haller DG, et al, editors. *AJCC cancer staging manual* (6th edn). New York: Springer-Verlag, 2002.
16. Fukuya T, Honda H, Kaneko K, Kuroiwa T, Yoshimitsu K, Irie H, et al. Efficacy of helical CT in T staging of gastric cancer. *J Comput Assist Tomogr* 1997;21:73–81.
17. Cho JS, Kim JK, Rho SM, Lee HY, Jeong HY, Lee CS. Preoperative assessment of gastric carcinoma: values of two-phase dynamic CT with mechanical IV injection of contrast material. *AJR Am J Roentgenol* 1994;163:69–75.
18. Minami M, Kawauchi N, Itai Y, et al. Gastric tumors: radiologic-pathologic correlation and accuracy of T staging with dynamic CT. *Radiology* 1992;185:173–8.
19. 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. *AJR Am J Roentgenol* 2005;185:1152–8.
20. Shimizu S, Tada M, Kawai K. Early gastric cancer: its surveillance and natural course. *Endoscopy* 1995;27:27–31.
21. Dinis-Ribeiro M. Chromoendoscopy for early diagnosis of gastric cancer. *Eur J Gastroenterol Hepatol* 2006;18:831–8.
22. Kim JH, Eun HW, Choi JH, Hong SS, Kang W, Auh YH. Diagnostic performance of virtual gastroscopy using MDCT in early gastric cancer compared with 2D axial CT: focusing on interobserver variation. *AJR Am J Roentgenol* 2007;189: 299–305.
23. Hahn FJ, Jacoby CG, Ehrhardt JC. The overshoot artifact as an aid in differentiating low densities on the computed tomographic scan. *J Comput Tomogr* 1978;2:149–51.
24. Lee JH, Jeong YK, Kim DH, Go BK, Woo YJ, Ham SY, et al. Two-phase helical CT for detection of early gastric carcinoma: importance of the mucosal phase for analysis of the abnormal mucosal layer. *J Comput Assist Tomogr* 2000;24:777–82.
25. Takao M, Fukuda T, Iwanaga S, Hayashi K, Kusano H, Okudaira S. Gastric cancer: evaluation of triphasic spiral CT and radiologic-pathologic correlation. *J Comput Assist Tomogr* 1998;22:288–94.