Preoperative Diagnosis of Gastric Tumors by Three-dimensional Multidetector Row CT and Double Contrast Barium Meal Study: Correlation with Surgical and Histologic Results

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Background/Purpose: Recent three-dimensional multidetector row computed tomography (3D MDCT) can provide detailed images of a gastric tumor, including its general contour, location and depth. We therefore evaluated the efficacy of MDCT in the differential diagnosis and staging of gastric tumors in patients prepared for surgery.

Methods: Seventy-nine patients with gastric tumors identified by gastric optical endoscopy were admitted for preoperative evaluation. All patients received double-contrast barium meal (DCBM) study and abdominal MDCT with 3D reconstruction before surgery. We compared the accuracy of MDCT with DCBM study in detecting and differentiating gastric tumors. In addition, the MDCT findings were correlated with surgical and pathologic results in gastric cancers for Borrmann type, T and N stages.

Results: Among the 79 patients with gastric tumors, there were 24 cases of early gastric cancer, 40 cases of advanced gastric cancer, 12 cases of gastrointestinal stromal tumor, and three cases of gastric lymphoma. Both MDCT and DCBM were very accurate in picking up the lesions (100%). The diagnostic accuracies of MDCT and DCBM were similar (94% vs. 96%) in differentiating mucosal and submucosal lesions as well as classification of Borrmann type in advanced gastric cancer (70% vs. 63%). In 64 patients with gastric cancers, there was good correlation between MDCT images and pathology in 73% of T staging and 69% of N staging.

Conclusion: MDCT has a similar high accuracy in the preoperative diagnosis of different gastric tumors compared with DCBM and provides additional information including tumor depth, lymph node and hepatic metastasis. Therefore, MDCT may be used as a primary tool for preoperative tumor diagnosis and staging. [J Formos Med Assoc 2007;106(11):943–952]

Key Words: barium sulfate, computed tomography, diagnostic use, neoplasms, stomach

The accurate characterization and preoperative staging of gastric tumors are important for planning the most appropriate therapy and for predicting prognosis. Traditionally, double-contrast barium meal (DCBM) or optical endoscopic studies have been used as the primary tool for preoperative diagnosis.1 However, these two methods are considered as stressful and uncomfortable to patients. Recent advances in computed tomography technology, including the...
introduction of multidetector row computed tomography (MDCT) and the development of real-time three-dimensional imaging systems, offer great potential for the clinical evaluation of gastric lesions. Some authors claim that 3D MDCT can provide transient transparent projection (TTP) images to replace DCBM and virtual gastroscopy (VG) images to replace optical endoscopy, and we believe that at least it would provide a topographic view of a lesion that would be complementary to the diagnosis. In addition, in patients with suspected gastric cancer, MDCT can provide major information that influence the prognosis, including the depth of wall invasion, the presence or absence of lymph node and/or distant metastasis.

Most previous studies of MDCT have focused on its performance in detecting gastric cancers, but other gastric tumors (such as gastrointestinal stromal tumor [GIST] and gastric lymphoma) that also require preoperative staging were not evaluated. In this study, MDCT findings of gastric lesions using 3D reconstruction were correlated with surgical and pathologic results to assess its utility and limitation in preoperative diagnosis and staging. We assessed if MDCT could be used as a primary tool, replacing the role of DCBM, to evaluate gastric lesions in patients with suspicious gastric tumors.

Material and Methods

Patients

Between February 2004 and January 2007, 79 patients (46 men, 33 women; mean age, 63 years; age range, 32–87 years) with recent (within 1 week before admission) optical endoscopic findings suggestive of a gastric tumor were admitted for further evaluation. All received DCBM and abdominal MDCT examination for preoperative tumor localization and diagnosis. Postoperative specimens were available in the patients, and MDCT as well as DCBM findings were correlated with the surgical and histopathologic results. All patients gave their written informed consent before the examinations.

CT examination

CT examinations were performed using a commercially available multidetector row CT scanner (LightSpeed QXi; GE Medical Systems, Milwaukee, WI, USA) which possessed 16 rows of detector arrays. Before CT examination, each patient was prepared by overnight fasting to empty the stomach. Butyl scopolamine (10 mg) was administered intravenously in all cases to reduce bowel peristalsis. Patients were advised to ingest two packs of effervescent granules with minimal water to obtain gastric distension. After a scout projection confirmed optimal air distension of the stomach, CT scanning was performed from the diaphragmatic dome to the lower edge of the stomach during a single breath-hold of 7–10 seconds. Unenhanced CT scanning was done in supine and prone positions. Scanning CT parameters included 16 × 1.25-mm beam collimation, 1.2 mm slice thickness, 2.5 mm reconstruction interval, a pitch of 6, 0.8 seconds gantry rotation time, table feed of 7.5 mm/rotation, field of view to fit the size of the individual patient (usually around 30–35 cm), 120 kVp and 80 mA. We reduced the tube current to decrease the radiation dose. Scanning in the supine and prone positions helped to shift fluid (gastric secretion) that might obscure underlying lesions and to distend the collapsed segments that were dependent on the opposite position. Preliminary evaluation of the air-distended stomach would serve to localize a potential lesion and to determine the body position for the post-contrast scan so that a potential lesion would be in the dependent portion of the stomach and covered by water. For post-contrast CT, all patients ingested 300–600 mL of tap water to distend the stomach. This allows good visualization of the enhancing gastric wall and avoids overshooting artifacts due to intraluminal air obscuring the normal gastric wall pattern. Thus, patients were scanned in the supine position when lesions were in the high gastric body to cardia; otherwise, they were scanned in the prone position. Each patient received an intravenous dose of 100 mL of contrast material at a rate of 3 mL/s. In our experience, it was adequate that the scan...
was initiated 50 seconds after the start of injection of contrast material for evaluation of tumor depth, extragastric invasion and hepatic metastasis. For post-contrast CT, the tube current was increased to 210 mA to improve the spatial resolution, and covered the diaphragm, liver and the entire stomach.

**DCBM study**
The DCBM study was usually performed on the day after CT examination. All studies were performed after oral administration of 200–250 mL of 220% wt/vol EZ-HD barium sulfate suspension (EZ-EM, USA). Oral administration of an effervescent powder and an intramuscular injection of butylscopolamine (10 mg) were used to establish adequate gastric distension and to minimize peristaltic activity. Multiple spot radiographs were obtained in various body positions under fluoroscopic control after adequate mucosal coating.

**Image analysis**
All preoperative images from DCBM and MDCT studies were reviewed by two radiologists in consensus without knowledge of the optical endoscopic findings and tumor location. If advanced gastric cancer was suspected, the tumors were classified according to the Borrmann system. If the mucosal layer was intact over a mass, a submucosal tumor would be considered. If the mucosal layer was unevenly thickened and showed abnormal enhancement on MDCT, a mucosal lesion or gastric cancer would be diagnosed. Early gastric cancer with ulceration would be considered when focal interruption of mucosa with adjacent nodularity or thickening was found. If only focal interruption of the mucosal layer was found, a benign gastric ulcer would be considered.

The CT dataset of each patient was transferred to an image processing workstation equipped with ADW 4.1 software (GE Medical Systems) for 3D reconstruction. Orthogonal sectional images of 0.6 mm thickness would be routinely obtained. Normally, one set of data would consist of three subsets of roughly 200 slices. The total evaluation time was about 15–20 minutes.

The precontrast images (where the stomach had been distended by effervescent powder) would undergo volume rendering to produce images: (1) profile of the entire air-distended stomach (TTP); (2) luminal surface view of the stomach mimicking optical endoscopy (hence VG). The gross appearance of a lesion under VG views provided a virtual gross view of the lesion with regard to its nature, e.g., margin of the lesion, smoothness of the tumor surface, presence of ulceration, nature of the adjacent mucosal folds.

The postcontrast images would be evaluated to identify focal wall thickening. The mucosal (inner) layer which is usually well enhanced would have higher attenuation than the less enhanced submucosal (middle) and muscular-serosal (outer) layers. Staging of T stage on MDCT was done according to the following:14 T1 (invasion to the mucosa or the submucosa, early gastric cancer), when the tumor was confined to the inner or middle layer of the gastric wall, with thickening of the mucosal layer but no obvious submucosal enhancement; T2 (invasion to the proper muscle), when the tumor invasion extended to the outer layer of the gastric wall but the outer surface of the gastric wall is smooth, with thickening of the inner layer and marked submucosal enhancement, or short stranding on the serosal surface less than 5 mm in length; T3 (invasion to the serosa), when a nodular or irregular surface of the gastric wall or perigastric infiltration was evident, with long stranding or a bumpy nodular appearance on the serosal surface greater than 5 mm; and T4 (invasion to adjacent organs or structures), when direct invasion or invasion of the tumor into a contiguous organ or structures was evident. A lymph node with no fat content and size (short-axis) larger than 1 cm, or a cluster of three or more nodes would be considered positive for metastasis. Imaging–pathologic correlations of lymph nodes were performed using group-by-group analysis. Our CT staging method for nodal metastasis was based on the nomenclature of the American Joint Committee on Cancer and the International Union Against Cancer.15
The pathologic reports of surgery specimens were reviewed. Histologic T staging was based on the international TNM classification. A stage of pT1 indicated tumor invasion into the lamina propria or submucosal layer; a stage of pT2, tumor invasion into the muscularis propria or subserosa; a stage of pT3, tumor penetration into the serosa without invasion of adjacent structures; and a stage of pT4, tumor invasion into adjacent structures. The location and morphology of the tumor, as described in the pathologic report, were used as a gold standard to calculate the preoperative diagnostic accuracies of DCBM and MDCT examinations. The accuracy of MDCT examination in the assessment of gastric cancer was also calculated, including Borrmann type, T staging and N staging. We used McNemar’s test to compare the diagnostic performance of DCBM and MDCT.

### Results

In the 79 patients, the final pathologic diagnoses were: 24 cases of early gastric cancer (EGC), 40 cases of advanced gastric cancer (AGC), 12 cases of GIST, and three cases of gastric lymphoma. All patients underwent operation for tumor excision except two cases of gastric lymphoma (total gastrectomy in 12, subtotal gastrectomy in 54, wedge resection in 11 and biopsy in 2). The tumors were located in the antrum \((n = 34)\), the body \((n = 24)\), the cardia \((n = 9)\), the fundus \((n = 6)\), or both body and antrum \((n = 6)\) of the stomach. Hepatic metastasis was noted in six patients, all of whom had AGC.

All 12 patients with GIST presented with submucosal tumors on pathology, and did not have extraserosal invasion, lymph node or distant metastasis. One of the three patients with gastric lymphoma received total gastrectomy, and pathology showed extraserosal invasion without lymph node or distant metastasis. The other two cases received only biopsy without surgery.

### Diagnostic accuracy of MDCT and DCBM for gastric tumors

The preoperative localization of gastric tumors was correctly assigned in all cases with both MDCT and DCBM. The accuracy for differentiating mucosal and submucosal tumors was high in both MDCT (94%) and DCBM (96%) \((p = 0.62)\) (Table 1). The overall accuracies of MDCT and DCBM in the morphologic classification of AGC were 70% and 63%, respectively \((p = 0.45)\) (Table 2). The performance of MDCT was similar to that of DCBM.

### T and N staging of gastric cancer with MDCT

The appearance of EGC included thickened layer of mucosa (Figures 1 and 2), while the appearance of AGC included abnormal enhancement extending...
deep into thickened submucosa, bumpiness and long stranding appearance on serosal surface that was more than 5 mm in height (Figures 3 and 4). A central depression in a tumor by VG was considered to be an ulcer. When the well-enhanced thin mucosal layer was smooth and only the less enhanced submucosal layer was thickened, a submucosal lesion was considered, e.g. lymphoma or GIST. Lymphoma presented with infiltrative submucosal mass whose extent was ill-defined whereas GIST was a well-demarcated lesion (Figure 5). An umbilication might be present on the surface of the lesion indicating ulceration.

The accuracy of CT in the preoperative determination of T stages was 73% (Table 3). Over-staging was more common in patients with T1-stage lesions and under-staging was more common in patients with T3-stage lesions using MDCT.
For preoperative determination of nodal stage (Table 4), MDCT had 69% (44/64) accuracy. For lymph node involvement, MDCT showed 88% sensitivity and 80% specificity.

**Discussion**

Traditionally, DCBM has been employed to detect or display the gross appearance of one gastric lesion that has been picked up by an endoscopist. Until recently, CT would be prescribed to obtain further information on the extent of the lesion, nodal involvement, or presence of hepatic metastasis. Recent 3D MDCT can provide TTP images similar to DCBM study, including general contour of the stomach, gross appearance and location of the gastric lesion. Therefore, we believe that the use of 3D MDCT may replace the role of DCBM in preoperative

**Figure 3.** Advanced T3 gastric cancer (Borrmann type 2) in a 47-year-old woman. (A) Coronal reconstructed image shows a protruding mass (arrows) with obvious submucosal enhancement in the antrum of the stomach with extragastric soft tissue invasion (arrowhead). Surgically, it proved to be pathologic stage T3. There is a cluster of small nodes (curved arrow) around the perigastric region, suggesting metastatic lymph nodes. Pathologic findings confirmed metastatic nodes. (B) Virtual gastroscopy image depicts a polypoid tumor with a smooth border (arrows). Borrmann type 2 gastric cancer was reported by optical endoscopy and confirmed by pathology.

**Figure 4.** Advanced T4 gastric cancer (Borrmann type 4) in a 70-year-old man. (A) Double-contrast barium meal study shows an irregular mass (arrows) at the body of the stomach. (B) Postcontrast axial reconstructed image shows a focal transmural hyperintense tumor (arrows) with an irregular outer border of the stomach and reticular strands in the greater omentum contiguous to the outer border of the tumor (arrowheads) in the inferior wall of the gastric antrum, suggesting omental invasion. Surgically, it proved to be pathologic stage T4 with omental involvement. The thickened mucosal layer with intense transmural enhancement, which is more clearly demonstrated in the multiplanar reconstructed image, is helpful to distinguish from submucosal tumor such as lymphoma.
tumor evaluation, and our results support that belief.

Our study showed that MDCT and DCBM had similar diagnostic accuracies in differentiating mucosal and submucosal tumors as well as classification of Borrmann type in AGC. It is noteworthy that appropriate gastric distension and mucosal enhancement were crucial in MDCT performance. When the gastric mucosa was not well distended or enhanced, it was difficult to differentiate mucosal from submucosal tumors as well as EGC from AGC because the folds were clumped together, giving a feeling of abnormal enhancement of the submucosal or muscular–serosal layer.

MDCT has several advantages over DCBM study. First, combining reconstructed MPR images and VG images provide information regarding the gross behavior of the lesion (i.e. Borrmann’s classification). Second, MDCT provides information concerning the depth of invasion by the tumor,
the presence of extragastric invasion, lymphadenopathy and distant metastasis, which cannot be seen in DCBM study. Third, MDCT is less skill-dependent, with less discomfort to the patient and thus more tolerable than DCBM study, especially in patients who are unable to cooperate with the examiner.

On unenhanced CT scan used for reconstruction of VG, the tube current is lowered to 80 mA and the patient scanned in the supine and prone positions because the presence of air-fluid level may immerse the underlying mucosa.12 Higher mA (210 mA) on contrast-enhanced CT could provide better spatial and contrast resolution in the evaluation of tumor depth, extragastric invasion and hepatic metastasis.

The advantages of VG include a wider field of view than optical endoscopy and the ability to freely adjust or navigate the viewing direction, so that tiny lesions are not obscured by very sharp turns.12,17,18 VG may provide alternative imaging for a patient in whom optical endoscopy or DCBM are not suitable (e.g. presence of severe obstruction). Elevated lesions are better depicted than non-elevated lesions such as ECG 2b and 2c. Malignant converging folds with clubbing or fusion, which are not depicted on MPR images alone, may be well-demonstrated by VG.19 In addition, fine mucosal details, color changes, texture, and hyperemia are native to optical endoscopy. New techniques such as color coding in proportion to the gastric wall thickness or texture mapping are works in progress that will hopefully overcome these problems.17 In short, MDCT may provide information that is comparable to that obtained by both optical endoscopy and DCBM with the addition of very important information such as extragastric invasion, nodal involvement, and hepatic metastasis for preoperative planning.17,20

Accurate evaluation of the local extent of gastric cancer (the so-called T stage) is of pivotal importance in the choice of optimal therapeutic strategy. Small T1 cancers have been shown to have a very low rate of nodal involvement; therefore, such patients would be good candidates for minimally invasive surgery such as endoscopic mucosal resection or laparoscopic surgical resection.21 In particular, depiction of serosal invasion is important because serosal involvement has been demonstrated to be a poor prognostic factor.22,23 When locally advanced gastric cancer with serosal invasion is present, a trial treatment with preoperative neoadjuvant chemotherapy is undertaken for down-staging to increase the chance for curative resection.24,25 Our results suggest that depth prediction solely by the enhancement of the submucosal layer may be inadequate. It has also been shown that the T staging of MDCT was limited in some cases such as T1 cancer with massive submucosal invasion of the cancer cells, T2

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**Table 3.** Diagnostic accuracy of multidetector row computed tomography for each T stage in gastric cancer with pathologic results as the reference standard (n = 64)*

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<thead>
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<th>Pathologic staging</th>
<th>CT staging</th>
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<tr>
<td>pT4</td>
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<td>Total</td>
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*Overall accuracy of T staging is 73%. cT = T staging by multidetector row computed tomography; pT = T staging by pathology.

**Table 4.** Diagnostic accuracy of multidetector row computed tomography for each N stage in gastric cancer with pathologic results as the reference standard (n = 64)*

<table>
<thead>
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<tr>
<td>pN1</td>
<td>4</td>
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<td>pN2</td>
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<td>pN3</td>
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<td>Total</td>
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*Overall accuracy of N staging was 69%, overall sensitivity was 88% and overall specificity was 80%. cN = N staging by multidetector row computed tomography; pN = N staging by pathology; N0 = no regional lymph node metastasis; N1 = 1–6 regional lymph node metastases; N2 = 7–15 regional lymph node metastases; N3 = more than 15 regional lymph node metastases.
cancers with perigastric inflammation or vascular or lymphatic engorgement, and T3 cancers with minimal infiltration of cancer cells into the perigastric adipose tissue.\textsuperscript{12} In a previous study, multidetector row CT scanning of patients with gastric cancer gave 93\% accuracy in the assessment of serosal invasion in patients with gastric cancer.\textsuperscript{10} Our results showed only 65\% (15/23) sensitivity for serosal invasion, which might be due to a stricter criterion in our study. Only those with bumpy projection more than 5 mm in height would be considered positive, otherwise inflammation would be considered.

In previous reports, regional lymph nodes are considered to be involved when the short axis diameter is greater than 6 mm for perigastric lymph nodes and greater than 8 mm for extraperigastric lymph nodes.\textsuperscript{26} When lymph nodes are larger than 10 mm in diameter, they are considered positive if CT attenuation values are greater than 100 HU.\textsuperscript{27} In our study, we considered a lymph node with no fat content and size larger than 1 cm, or a cluster of three or more nodes indicating positivity for invasion. But this criterion only showed 88\% sensitivity and 80\% specificity. Although there is a clear correlation between lymph node size and cancer involvement, CT has significant inherent limitations in the nodal staging of gastric cancer because of the high frequency of microscopic nodal invasion (involvement of normal-size nodes) and the poor differentiation between reactive or inflammatory or metastatic nodal enlargement.

The limitation of our study is that it was retrospective and included only patients referred to our hospital for further assessment and surgery. Although blinded to the endoscopic, surgical and histopathologic results, the observers were aware of the presence of a tumor. The study may therefore be biased toward patients with more advanced disease and result in a higher diagnostic rate of gastric cancers. In addition, we only performed single phase (50 s) in contrast-enhanced images, which might decrease the accuracy for T staging.\textsuperscript{19} However, dynamic technique would increase the radiation dose and we suggested that combination of the VG and MPR might still provide similar diagnostic information for TNM staging of gastric tumors.

In conclusion, MDCT has high accuracy in the preoperative diagnosis of different gastric lesions and provides valuable information including tumor depth, morphology, lymph node and hepatic metastasis in only one examination. It is unlikely for MDCT to replace the role of optic endoscopy because MDCT cannot take biopsy of the suspected gastric lesion. However, with its improved performance and 3D reconstruction, MDCT may be used as the primary tool and replace DCBM study in the preoperative diagnosis of patients with gastric tumors.

References