The detection of gastric neoplasia has traditionally been limited to barium examination and direct visualization at endoscopy. The rapid development of techniques such as multidetector computed tomography (MDCT) and endoscopic ultrasound (EUS) has resulted in more accurate diagnosis and staging of gastric neoplasia. In this review we describe the normal anatomy of the stomach with multi-modality illustrations and review the imaging manifestations of gastric neoplasia, including adenocarcinoma, lymphoma, neuroendocrine and gastro-intestinal stromal tumours. We also describe the optimal techniques for up-to-date and accurate gastric imaging, outlining the role of MDCT and EUS.

Introduction

The assessment of gastric neoplasia has until recently been limited to double-contrast barium examination and upper gastrointestinal endoscopy. With the advent of multidetector computed tomography (MDCT) and endoscopic ultrasound (EUS), the ability to detect, diagnose, and characterize disease has improved.

The main role of MDCT and EUS imaging of the stomach is in the preoperative staging of gastric adenocarcinoma. These two imaging methods have complementary roles. In patients with resectable disease by CT criteria, EUS, with its ability to delineate the five gastric wall layers (superficial mucosa, deep mucosa, submucosa, muscularis propria, and serosa), can assess the depth of local tumour infiltration, as well as lymph node involvement. EUS also has a role in the histological diagnosis of submucosal tumours using EUS-guided fine-needle aspiration (EUS-FNA) and Trucut-type needle biopsy. MDCT enables assessment of both the primary tumour and distant metastases, and also permits accurate diagnosis and staging of gastric tumours other than adenocarcinoma.

In this review we describe the use of MDCT and EUS in the assessment of gastric neoplasia, including adenocarcinoma, lymphoma, gastrointestinal stromal tumours (GIST), gastric carcinoid tumours, and metastases.

Anatomy

With the increasing availability of MDCT and EUS there is a need for an in-depth understanding of multiplanar gastric anatomy. The gastric cardia, body, fundus, antrum, and pylorus are now easily appreciated using MDCT multiplanar reformats. While the layers of the gastric wall can be readily discerned using EUS (Fig. 1), with optimal technique, limited gastric wall anatomy can also be appreciated using MDCT. The wall may be seen as a three-layered structure with maximum enhancement of the mucosa, a low attenuation stripe representing submucosa (most likely due to fat deposition), and an outer layer of intermediate attenuation, representing muscularis propria and serosal layer (Fig. 2).

Dual-phase CT imaging allows optimal visualization of the vasculature of the stomach. The
arterial supply consists of the left gastric, the right gastric, and right gastroepiploic branches of the hepatic, and the left gastroepiploic and short gastric branches of the splenic artery. The venous drainage is via the splenic vein, the superior mesenteric vein, and the portal vein. Local regional gastric lymph node anatomy can be sub-classified into four compartments (Table 1).

Awareness of the anatomical relations of the stomach is vital in determining the extent of local disease spread. The anterior relations of the stomach are the diaphragm, abdominal wall, and left lobe of the liver. The posterior relations are the lesser sac, pancreas, spleen, left kidney, left adrenal gland, and transverse mesocolon. In the staging of advanced gastric tumours, coronal and sagittal reconstructions improve the accuracy of assessment of local invasion into these adjacent structures.²

Technique

The use of MDCT improves the assessment of gastric disease, in particular allowing more detailed preoperative staging of gastric tumours: faster imaging times result in less respiratory artefact; thinner collimation permits detection of more subtle pathology; improved quality of three-dimensional (3D) datasets facilitates multiplanar reconstruction (MPR) and permits 3D volume rendering. Image reconstruction in the axial, coronal, and sagittal planes increases confidence with interpretation and provides enhanced characterization of disease.

Incorporating customized protocols can further optimize MDCT imaging of the stomach.³ Gastric tumours often appear as segmental or diffuse wall thickening that may demonstrate enhancement unlike that of the normal adjacent gastric wall. The use of negative oral contrast medium, i.e., water, provides low attenuation within the gastric lumen and improves visualization of the enhancing gastric wall. This permits more accurate

Table 1  Gastric regional lymph node anatomy

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<th>Compartments</th>
<th>Node groups</th>
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<td>I</td>
<td>Perigastric lymph nodes.</td>
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<td>II</td>
<td>Lymph nodes along the left gastric artery, along the common hepatic artery, around the coeliac axis and along the splenic artery.</td>
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<td>III</td>
<td>Lymph nodes in the hepatoduodenal ligament, posterior to the head of the pancreas and at the root of the mesentery of the transverse colon. When the tumour is located in the lower third of the stomach, lymph nodes along the splenic artery are classified as compartment III.</td>
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<td>IV</td>
<td>Lymph nodes along the superior mesenteric artery and para-aortic lymph nodes.</td>
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Modified from JRSGC, 1995.¹

Gastric malignancy involving lymph nodes distant to these regional groups constitutes metastatic disease.

Figure 1  Normal layers of the gastric wall as defined by endoscopic ultrasound. m, Mucosa; sm, submucosa; mp, muscularis propria; s, serosa.

Figure 2  Normal gastric wall anatomy as demonstrated using MDCT. Distinction between mucosa, submucosa, and muscularis is often possible, provided the stomach is adequately distended.
delineation of tumour morphology and, in the case of adenocarcinoma, can result in T staging accuracy of up to 93%. More recently, the use of a combination of water and air distension has been described, which might further improve accuracy in staging.

In our practice, and as recommended by the Royal College of Radiologists, adequate distension of the stomach is achieved by the administration of 1000 ml water, of which 400 ml is administered immediately before the examination. If there is inadequate distension, distinguishing normal anatomy from tumours can be difficult particularly at the gastro-oesophageal junction and pylorus. Conversely, in an adequately distended stomach, any abnormal areas of decreased distension, diffuse wall thickening, or lack of gastric rugae become more readily apparent, as might be seen in linitis plastica.

Dual-phase imaging, in both the arterial and portal venous phases, allows detection of subtle gastric mucosal abnormalities and also improves the accuracy of T staging of adenocarcinoma. At our institutions, we have found that imaging the chest and stomach at 30 s post-injection of 100 ml Omnipaque 300 (at 4 ml/s) and the abdomen (including the whole stomach) at 70 s post-injection best demonstrates gastric disease.

Correct positioning of the patient during the examination is important as tumours in the antrum and pylorus are often better delineated when the patient is imaged in the prone position, whereas fundal and body tumours are better imaged in the supine position. The choice of patient position can, therefore, be determined by the site of the tumour seen at endoscopy. Some authors have advocated combining prone and supine imaging, but, with the associated increased radiation dose to the patient and the lack of evidence to support this combination, we do not use this technique.

In selected cases, EUS has a complementary role in the preoperative local staging of gastric neoplasia. Two different types of instruments are available: (1) a radial machine with a mechanical or electronic ultrasound transducer that is built into the tip of a flexible endoscope, which provides a 360° imaging plane perpendicular to the axis of the echoendoscope, and (2) an electronic linear array endoscope, where the 180° sector is parallel to the scope axis. Linear array echoendoscopes also permit real-time EUS-FNA and biopsy of structures within, or in close proximity to, the gastrointestinal tract. The high ultrasonic frequencies (5–12 MHz) enable the identification of lesions as small as 2–3 mm and the delineation of five layers of the bowel wall. Miniprobe ultrasound probes are thin devices that can be passed through the working channel of a conventional endoscope, producing a high resolution (15–30 MHz), circumferential image similar to that of the radial echoendoscope. With these higher frequencies, up to nine layers of the GI tract wall can be visualized but only to a limited tissue depth of 1–3 cm. Miniprobes are of particular value when assessing early gastric cancers or small submucosal lesions.

### Gastric adenocarcinoma

Adenocarcinoma is the commonest gastric malignancy, representing over 95% of malignant tumours of the stomach. Gastric cancer is the fifth leading cause of cancer mortality in the UK for men and the seventh leading cause of cancer mortality for women. Overall, the 5-year survival rate remains less than 20% in the UK. Worldwide the incidence of gastric carcinoma is highest in Japan with 62.1 cases diagnosed per 100,000 as compared with 12.8 cases in Western Europe.

Risk factors associated with the development of gastric adenocarcinoma are salt-rich diets, smoked or poorly preserved foods, nitrates, nitrites, and secondary amines. In addition, there is a well-recognized association with *Helicobacter pylori* infection. Other associated risk factors include chronic atrophic gastritis, smoking, obesity, Métrier’s disease, and gastric polyps.

Gastric adenocarcinoma is pathologically staged using the TNM system (Table 2). Early gastric

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<th>Table 2 Pathological staging of gastric carcinoma using T (tumour), N (node) and M (metastases) system (AJCC)</th>
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adenocarcinomas (≤T1 tumours) are limited to the mucosa or submucosa, regardless of the lymph node status. Tumours invading the muscularis propria and subserosa are classified as T2. T3 tumours penetrate the serosa (visceral peritoneum), whereas T4 tumours invade adjacent structures. The differentiation of T3 and T4 tumours is especially important in preoperative staging as extensive invasion reduces the possibility of resection (Fig. 3). The majority of patients unfortunately have advanced adenocarcinoma at the time of diagnosis, which invades the muscularis propria (≥ T2 disease). With advancing disease, tumours extend proximally and distally within the stomach, as well as demonstrating vertical progression through the layers of the gastric wall. Early gastric adenocarcinomas may manifest as elevated, flat, depressed, or ulcerating lesions. Advanced carcinomas more commonly manifest as segmental or diffuse thickening with associated lobulation, with or without ulceration. MDCT, with its near-isotropic imaging of the stomach, aids the detection and radiological staging of gastric adenocarcinoma (Table 3). In a recent study by Chen et al., a statistically significant improvement in the accuracy of T-staging was demonstrated with MPR (89%) compared with axial images alone (73%). However, EUS is currently the most reliable method for preoperative determination of T-stage with a diagnostic rate of 78–94%. However, it is more invasive than CT and provides limited information on the presence of distant nodal disease or metastases. It has a particular role in the staging of early gastric cancer, as these lesions are confined to the mucosa or submucosa and may be amenable to endoscopic mucosal resection.

Nodal staging is inherently difficult whatever the technique used; enlarged nodes may subsequently be proven to be inflammatory, whereas normal-sized nodes may be metastatic (Table 3). At present it would appear that EUS and CT confer similar degrees of accuracy in N staging. In a study of 63 patients using MDCT, the accuracy of lymph node staging was 75% for MDCT and 79% for EUS.

Figure 3 MDCT images depicting different morphological patterns and stages of gastric adenocarcinoma. (a) Tumour with an elevated morphological pattern demonstrating transmural enhancement with preservation of a clear fat plane, which are radiological features suggestive of a T2 tumour; pathological correlation (haematoxylin and eosin staining (H & E)) of this lesion (b) demonstrates muscularis invasion (circled) without serosal involvement (arrows), confirming this to be a T2 lesion. (c) A tumour demonstrating an ulcerating pattern, a smooth outer border of the thickened gastric wall and preservation of a clear fat plane, pathologically confirmed to be T2. (d) Tumour demonstrating irregular thickening of the gastric wall and blurring of the fat planes around the lesion, which is radiologically suggestive of a T3 tumour; pathological correlation (H & E) of this lesion (e) revealed serosal involvement (arrow), confirming this to be a T3 lesion. (f) A T4 tumour demonstrating local organ invasion involving left lobe of liver and extending to the diaphragmatic crura. (Pathology slides courtesy of Dr Waria Mohamid.)
The use of MPR reconstructions with coronal and sagittal reformats further improves the evaluation of nodal disease (Fig. 4). A recent study achieved nodal staging accuracies of 78% with MDCT MPR images and 71% with axial images alone. The accuracy of MDCT in nodal staging is greatest with more advanced disease. A recent study achieved accuracies of 90 and 71% with MDCT for the detection of lymph node metastases from advanced and early gastric adenocarcinomas, respectively.

Given that EUS can identify lymph nodes as small as 3 mm, information regarding the N status of a neoplasm can often be elicited. EUS criteria have been developed to characterize whether a potential lymph node is benign or malignant, with reported accuracies of 80–100% when all the following features are present: hypoechoic structure, sharply demarcated borders, rounded contour, and a size below 10 mm. Larger studies will, however, be required to compare the accuracy of MDCT with EUS in the assessment of nodal disease in the future.

Although EUS can potentially detect liver, mediastinal, and even peritoneal metastases, it is not primarily employed for the assessment of distant disease and MDCT remains the initial imaging method of choice (Fig. 5).

### Gastric lymphoma

The stomach is the most common site of gastrointestinal lymphoma. Overall, however, lymphoma accounts for less than 5% of all gastric malignancies with non-Hodgkin’s lymphoma of B-cell origin being the most common subtype. Lymphoma of mucosa-associated lymphoid tissue (MALT) is a distinct entity within the group of extra-nodal marginal zone B-cell lymphomas and is associated with H. pylori infection and chronic gastritis.

MALT lymphomas are usually associated with a more indolent course, although in some cases progression to high-grade B-cell non-Hodgkin lymphoma may occur.

Lymphoma can be classified radiologically as: infiltrative, ulcerative, polypoid, nodular, or combined. Infiltrative is defined as focal or diffuse enlargement of the rugae with or without luminal narrowing. Polypoid is defined as an intraluminal mass with or without ulceration. Nodular is defined as multiple or innumerable discrete nodules. There are certain imaging features of lymphoma that aid in the differentiation from other malignancies. The gastric wall thickening is typically more diffuse and homogeneous than with adenocarcinoma. The fat plane around the stomach is also more likely to be preserved (Fig. 6). Lymphoma rarely results in luminal narrowing and obstruction, even in the presence of diffuse infiltration and it most commonly involves the distal half of the stomach. In contrast to gastric adenocarcinoma, lymphoma often involves more than one site within the stomach. The presence of lymph nodes on either side of the mesenteric vessels (the sandwich sign) is also a feature of gastric lymphoma. Extension of lymph node involvement below the level of the renal veins may further aid in the differentiation from adenocarcinoma.

Although CT is the main imaging technique used for the initial assessment and staging of gastric lymphoma, EUS has a complementary role in assessing gastric wall involvement and local lymph node status, as well as in tissue acquisition from thickened gastric folds or nodes if endoscopic biopsies are negative.

### GISTs of the stomach

GISTs are a heterogeneous group of smooth muscle mesenchymal tumours of the gastrointestinal tract. Grading of their malignancy is a continuum based on assessment of tumour size and mitotic index. The stomach is their most common site of
Tumours that arise in the stomach tend to have a less aggressive histology compared with other GISTs, but approximately 50% will have metastasized by the time of presentation.\(^{28}\) The malignant subgroup of gastric GISTs represent only about 3% of all stomach malignancies.\(^{29}\) Very rarely, gastric GISTs may be associated with a functioning extra-adrenal paraganglioma and pulmonary chondroma, as part of the so-called Carney triad.

MDCT forms the basis of diagnosis, staging and post-treatment follow-up. The common imaging features are of a well-circumscribed heterogeneously enhancing, round, exophytic tumour, manifesting as a dominant mass extrinsic to the wall of the stomach (Fig. 7). Smaller lesions may appear homogeneous in density. Central fluid attenuation, indicative of necrosis, is common and mural calcification is also a recognized feature. The liver is the most common site for metastasis\(^{30}\) and MDCT

Figure 4  A coronal oblique reformat (a) demonstrates focal gastric wall thickening (arrowhead) but preservation of a clear fat plane around the lesion, suggestive of a T2 tumour. Even small adjacent gastro-hepatic lymph nodes can be identified using multiplanar reconstructions (arrow). (b) Histopathological correlation demonstrates the exophytic, ulcerated tumour located in the stomach near the gastro-oesophageal junction (arrow). (c) Moderately and poorly differentiated adenocarcinoma of the gastro-oesophageal junction invading the inner layer of the muscularis propria, confirming a T2 adenocarcinoma. (d) The regional lymph node identified on MDCT (a) was pathologically confirmed as a metastatic adenocarcinoma of the stomach without extracapsular spread. (Pathology slides courtesy of Dr Michael England.)

Figure 5  Advanced metastatic gastric adenocarcinoma at MDCT. As well as para-aortic lymph nodes, metastases to the liver and lung are evident.
may also demonstrate adjacent organ invasion, ascites and omental or peritoneal spread. Associated lymphadenopathy is, however, uncommon in contrast with gastric adenocarcinoma or lymphoma. EUS has been used in both the diagnosis and staging of submucosal tumours (Fig. 8), and furthermore, some may be amenable to endoscopic resection.

**Gastric neuroendocrine tumours**

The most recent Surveillance, Epidemiology and End Results (SEER) data from the USA show that gastric neuroendocrine tumours represent 8.7% of all gastrointestinal neuroendocrine tumours. These tumours are uncommon and represent only 1.8% of gastric malignancies. Their rare occurrence and variety of clinical and radiological presentations makes diagnosis difficult. Most gastric neuroendocrine tumours are enterochromaffin-like (ECL) cell tumours, which occur in the oxyntic mucosa in the gastric fundus and body. Three distinct clinico-pathological subtypes are recognized.

Type 1 ECL cell tumour — this is the most common subtype, accounting for 74% of all gastric endocrine tumours. There is a male preponderance (2.5:1), with a mean age at presentation of 63 years. These lesions occur as small multiple mucosal nodules, which arise in the setting of chronic atrophic gastritis and chronic hypergastrinaemia. These tend to exhibit benign biological behaviour with lymph node metastases reported in only 5%.

Type II ECL cell tumour — this uncommon group represents 6% of all gastric endocrine neoplasms, showing no sex preponderance and occurring at a mean age of 50 years. Usually multiple, these tumours are more variable in size and arise in patients with multiple endocrine neoplasia (MEN) type I and Zollinger–Ellison syndrome. Up to 30% of patients with MEN I develop gastric neuroendocrine tumours. These tumours are prone to nodal metastasis, with rates of up to 30% reported.

Type III ECL cell tumour — this group represents 13% of all gastric endocrine neoplasms, has a marked male preponderance (2.8:1) and presents at a mean age of 50 years. Usually sporadic, solitary, and large (>2 cm) masses, these tumours are not associated with hypergastrinaemic states. Metastases are found in 50–70% at presentation and carcinoid syndrome is often a feature in those with hepatic metastases.

In the staging of gastric neuroendocrine tumours with MDCT, arterial and portal venous phase imaging are essential to evaluate the primary gastric lesions, as well as to detect potential secondary deposits in the liver.

**Metastases**

The stomach is an unusual site for metastases. Gastric metastases are found at autopsy in less than 2% of patients who die of carcinoma. The most common primary tumours that metastasize to the stomach are malignant melanoma, breast carcinoma, and lung carcinoma (Fig. 10). Morphological features of gastric metastases include multiple nodules, bull’s eye appearance, extrinsic...
Small GISTs are frequently homogeneous in attenuation. As they enlarge, however, these tumours often demonstrate heterogeneous enhancement (arrows) and in this case peritoneal deposits are also evident (arrowhead) adjacent to the greater curve of the stomach (a). In another patient a large GIST tumour (b) is seen to have a central area of low attenuation, suspicious for central necrosis. (c) Histopathological correlation confirmed a 90 mm partly necrotic tumour (arrowheads), arising from the wall of the stomach (arrow). (Pathology slides courtesy of Dr Rodriguez-Justo.)

Gastrointestinal stromal tumour as demonstrated at EUS.

Type II ECL cell gastric neuroendocrine tumours are seen in up to 30% of patients with MEN I.
mass lesions, ulceration, and polypoid tumor masses.37

Conclusion
The development of EUS and MDCT has enabled more accurate diagnosis and staging of gastric neoplasia. Where available, EUS provides a complementary role in the assessment of both the primary tumour and local node involvement. However, with the ongoing advances in MDCT technology, such as the development of virtual gastroscopy, and dedicated gastric protocols, these roles will evolve further.

References