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The modern methods of gastric imaging

Imaging of the stomach has undergone profound changes in the last 20 years. Plain film radiography, barium studies (double contrast) – while still important in some indications such as detection of lesions, diagnostic and differentiating, staging, follow-up – are being used much less frequently.

This is partly due to the advent availability of endoscopy but more importantly due to the development of the modern cross-sectional imaging modalities such as ultrasound endoscopy, computed tomography – multidetector and magnetic resonance imaging.

The diagnostic methods are as follows:

BARIUM STUDIES

The routine contrast examination for gastroduodenal disease is the double contrast barium meal – DCBM (16). This has been found consistently superior to single contrast studies. There are many variations in technique for performance of the DCBM, but a frequently used method is a biphasic one that incorporates elements of the single contrast examination. The single contrast barium meal is occasionally justified in very elderly, sick or immobile patients and can be used to answer specific questions, such as determining the presence of gastric outlet obstruction. Water soluble iodinated contrast media are used where there is suspected perforation or where a recent anastomosis is being tested. The most common contrast is 76% sodium methylglucamine diatrizoate ("Gastrografin").

The aim of the DCBM is to see, by appropriate positioning, all parts of the oesophagus, stomach and proximal duodenum in double contrast with good mucosal barium coating, adequate gaseous distension and hypotonia. A measure of good coating is the visualisation of the *areae gastricae* which are seen as a mosaic-like pattern in the stomach (7, 16, 17). These represent the areas about 1–4 mm in diameter, in the centre of which the gastric glands open. Their visualisation depends on radiographic technique, barium density and the amount of mucus in the stomach. They are most often seen in the gastric antrum and body (7, 17) – Fig. 1. DCBM shows small superficial changes, such as plane ulceration, erosions, scars. This method is useful in detection of early gastric cancer – 2 cm (14).

Mentioning early diagnosis of gastric cancer one should ask a question what the early diagnosis means. The latest research proves that in cancer morphogenesis a few stages leading to the development from ca *in situ* to minor or major tumour, can be isolated. The evolution of changes can be presented as follows: unchanged mucosa – gastritis – gastritis + ca *in situ* –superficial carcinoma – tumour (11).

Carcinoma *in situ* means changes in epithelial cells limited to the submucosa. Superficial carcinoma, with which clinical term of early carcinoma is related, means the period of changes limited to the submucosa. For a relatively long time this stage can be limited to the mucosa and not penetrating

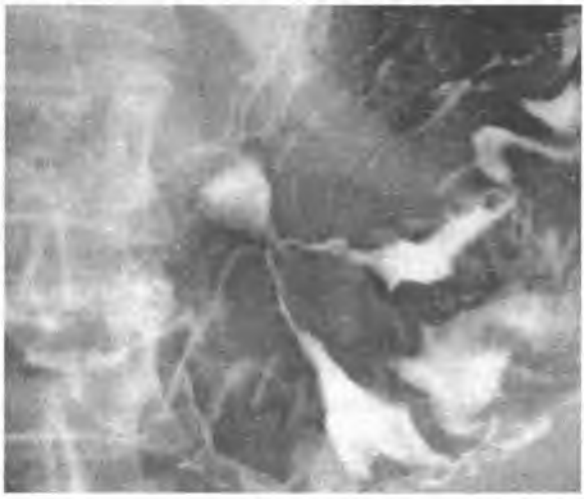

Fig. 1. Double contrast barium meal of stomach – ulceration in the prepyloric part of stomach

towards muscular membrane and without lymphatic metastases. The period of time between ca *in situ* and tumour is from one to three years. This is an important statement because it gives chance both to a patient and to a doctor whose responsibility is diagnosis as well as an appropriate treatment (2, 14).

According to Japanese authors early gastric cancers are curable lesions, with 5-year survival rates of more than 90%. Conditions that predispose patients to the development of gastric carcinoma include atrophic gastritis, pernicious anemia, gastric polyps, partial gastrectomy and Menétrier disease. About 30% of cancers are located in the antrum, 30% in the body, and 30% in the fundus or cardia region. The remaining 10% are diffusely infiltrating lesions that involve the entire stomach. Scirrhous carcinoma accounts for 5%–15% of all gastric cancers and typically infiltrates the gastric wall. It is usually limited to the submucosa as *linitis plastica* with stiff, inflexible wall (1).

ENDOSCOPIC ULTRASONOGRAPHY

Conventional US has little place in gastroduodenal disease in adults, although wall thickening due to gastric carcinoma and inflammatory disease in the antrum can often be seen. Real time US can also be used to study antropyloric emptying and motility non-invasively. Endoscopic ultrasound is accurate in the T and N staging of gastric adenocarcinoma and the confirmation of *linitis plastica*. It may also be used to detect and stage gastric lymphoma and image submucosal tumours such as smooth muscle lesions and distinguish them from extrinsic impressions seen at endoscopy or barium studies (14).

COMPUTED TOMOGRAPHY

The importance of CT in staging gastric cancer is becoming more and more meaningful. CT is used as an additional method to double contrast barium meal and EUSG mainly with patients with diagnosed gastric carcinoma, lymphoma or submucosal tumours.

Nowadays introducing multidetector computed tomography to radiology imaging is becoming more and more important.Transverse scans achieved in CT allow to evaluate mural thickness of the stomach. In order to differentiate between a proper gastric wall and an infiltrated one an intravenous contrast agent should be administered.•Computed tomography allows to evaluate a gastric lumen, wall and adjoining structures (4, 11).

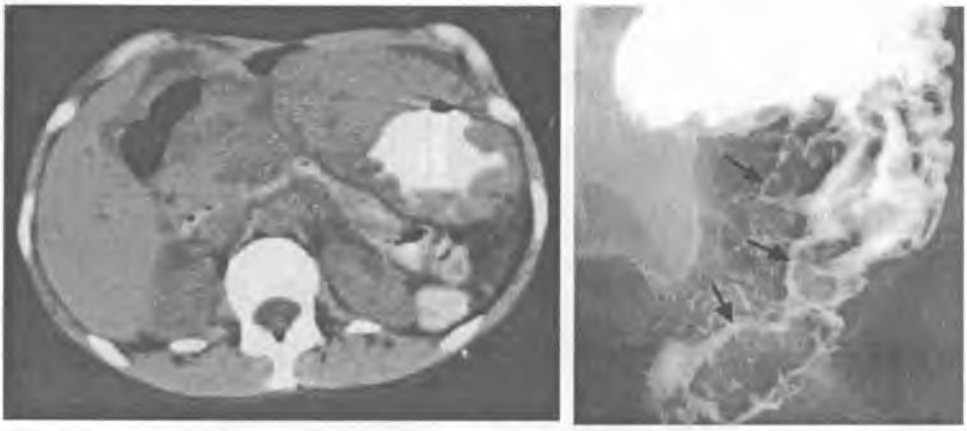

Fig. 2. Immunocytoma in: a) computed tomography, b) double contrast barium meal

An optimum CT technique requires high spatial resolution, proper gastric distension, and proper timing of contrast media injection to detect subtle changes in the gastric wall and to accurately stage tumours.

Preliminary preparation of the small bowel with oral contrast medium is useful, but 300 ml of plain water is better low-density contrast agent with which to distend the stomach immediately prior to scanning, allowing intravenous contrast enhancement of the wall to provide satisfactory delineation of the tumour. Effervescent agents also distend the stomach but result in greater streak artefacts from the resultant gas/liquid interface (9).

Normally, a dynamic sequential scan following intravenous bolus administration of contrast is used to show vascular structures and for the identification of liver metastases. Recent CT technological advances allow helical (spiral) CT images of the upper abdomen to be obtained with a single breath-hold.

Multidetector computed tomography offers new opportunities in imaging of the gastrointestinal tract. When thin collimation is used, near-isotrophic imaging of the stomach is possible, allowing high-quality multiplanar reformation and three-dimensional reconstruction of gastric images. In contrast to gastroscopy and double-contrast studies of the stomach, CT provides information about both the gastric wall and the extragastric extent of disease (Fig. 3a, b, 4a–e). Preoperative staging of gastric carcinoma appears to be the main clinical indication for multidetector CT. In addition, multidetector

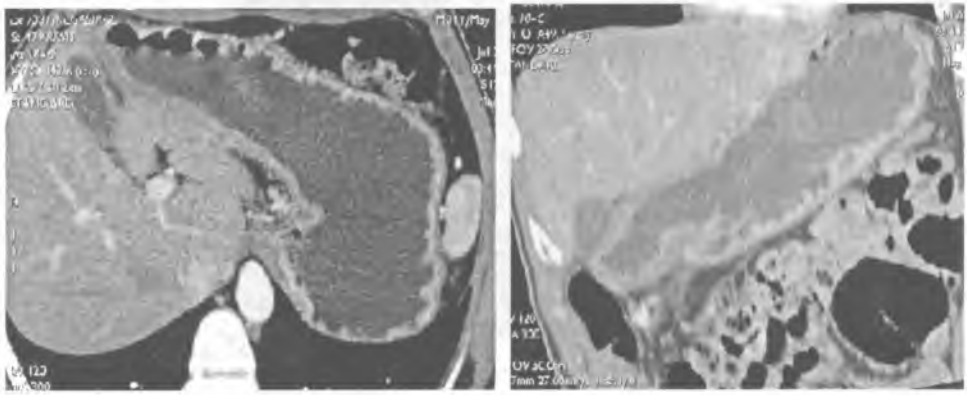

Fig. 3. Image of stomach in multidetector tomography; a) arterial phase, b) parenchymal phase

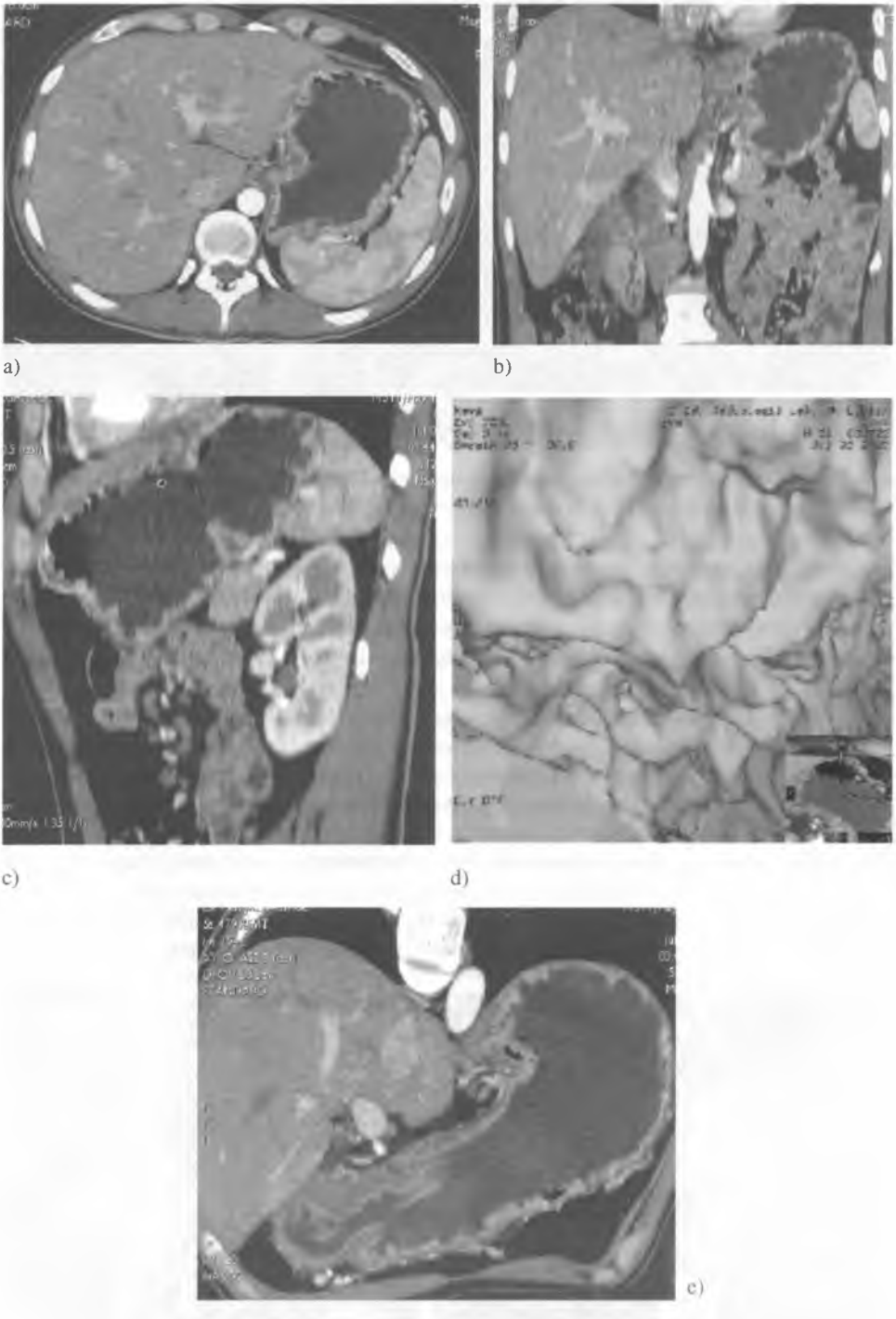

Fig. 4. Image of stomach in multidetector tomography in different types of reconstructions; a) axial MPR view, b) coronal MPR view, c) sagittal MPR view, d) virtual endoscopy, e) curved MPR view; antrum gastritis

CT allows detection of other gastric malignancies (lymphoma, carcinoid tumours, metastases, gastrointestinal stromal tumours) and benign gastric tumours (neural tumours, polyps) – Fig. 2a,b. Gastric inflammation (gastritis, ulcers, Menétrier disease) and miscellaneous gastric conditions (emphysema, gastric outlet obstruction, varices, hernias) can also be visualized with multidetector CT (1, 5) – Fig. 5–6.

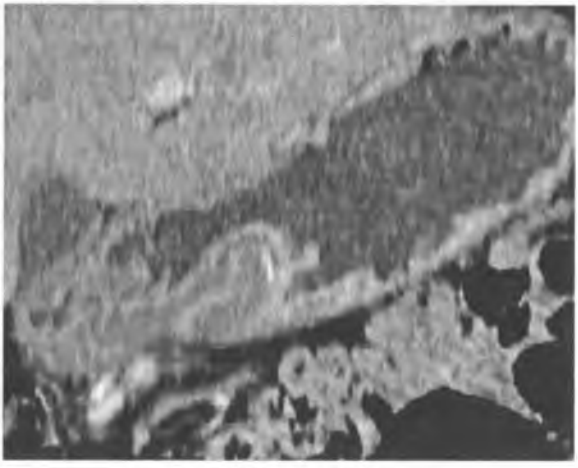

Fig. 5. MSCT – ulceration of *bulbus duodeni* with features of gastritis in the region of prepyloric part

Fig. 6. Sliding hernia of the stomach; a) in oblique MPR reconstruction, b) in 3D volume rendering

According to the American Joint Committee on Cancer (10), N staging depends on the number of positive perigastric lymph nodes: N1 = one to five, N2 = six to 15, N3 = > 15 affected lymph nodes.

Lymph node assessment for metastatic spread remains a challenge even with multidetector CT. However, improved evaluation appears possible if both morphologic and enhancement criteria are used.

Lymphoma involves the stomach more frequently than any other portion of the gastrointestinal tract. Primary gastric lymphomas are confined to the stomach and regional lymph nodes (about 35% of gastrointestinal lymphomas) and are predominantly non-Hodgkin lymphomas of B-cell origin (10).

Early gastric lymphoma is confined to the mucosa, with an average size of only 3.5 cm at diagnosis. Gastric lymphomas are usually advanced lesions with a mean diameter of 10 cm. Most cases involve the antrum and body, although the entire stomach can be involved (10, 15).

Table 1. The suggested CT techniques for examination of the stomach (11)

Phase of examination	Aspect of technique	Parameters
Patient preparation	Fasting	No solid food for at least 6 h
	Oral contrast material	1000–1500 ml of water or a flavored methylcellulose preparation
	Hypotonia	20 mg of intravenous scopolamine
Scanning	Section collimation	0.75–1.25 mm (four-, eight- and 16-row scanners)
	Pitch	>1.0
	Reconstruction section thickness	1.0–1.5 mm
	Reconstruction increment	0.7 mm
Contrast material injection	Volume of contrast material	120 ml (or 1.5ml/kg of body weight)
	Flow rate	4 ml/sec
	Scanning delay from start of injection	Arterial phase: 30 sec Portal venous phase: 60 sec

There are four gross pathologic types of gastric lymphoma. Infiltrative gastric lymphomas manifest as focal or diffuse enlargement of gastric folds due to submucosal spread of tumour. One or more ulcerated lesions characterize ulcerative gastric lymphoma. Polypoid gastric lymphomas are characterized by intraluminal masses that may simulate polypoid carcinomas. Multiple submucosal nodules ranging in size between several millimeters and several centimeters characterize nodular gastric lymphoma (10, 15).

Gastrointestinal stromal tumours (GISTs) are relatively common tumours of the stomach, occurring in up to 46% in some *post mortem* series (2). Many but not all mesenchymal tumours, previously diagnosed as leiomyomas, leiomyoblastomas, leiomyosarcomas, and so on are now considered GISTs on the basis of specific immunohistochemical criteria (12). The malignant variety of GISTs represents only about 3% of all malignant gastrointestinal tumours. Approximately 60%–70% are found in the stomach (4, 12). It is known that 10%–30% of GISTs are malignat and the risk of malignancy increases with extragastric location, diameter greater than 5 cm, and extension into adjacent organs (6, 13). Before and during surgery it is difficult to distinguish benign and malignant lesions. As with leiomyomas and leiomyosarcomas, intramural endogastric and exogastric lesions can be distinguished. Leiomyomas and leiomyosarcomas of the stomach are very rare. Age is also a relevant factor, with GISTs common in those between 50–60 years of age, and less common in those aged 40 years or younger. The incidence of malignancy is higher in the younger age group (12).

The majority of GISTs are asymptomatic, with a large proportion being found incidentally at autopsy or during other surgical procedures. Macroscopically GISTs are smooth submucosal projections into the stomach lumen (6).

Table 2. The CT criteria for T and N staging of gastric cancer (5)

Stage	CT Criteria
T0	No evidence of alteration of the gastric wall with a normal fat plane
T1	Nontransmural marked enhancement with focal wall thickening or marked enhancement only without wall thickening in a single-layer pattern, or thickening and marked enhancement without abrupt obliteration of the middle and outer layers in a multilayered pattern
T2	Transmural enhancement with focal wall thickening in a single-layer pattern, or both abnormal enhancement and abrupt obliteration of the middle layer in a three-layered pattern or of the outer layer in a two-layered pattern; smooth outer border of the thickened gastric wall or a few small linear strands of soft tissue extending into the fat plane
T3	Reticular or irregular outer border of the thickened gastric wall or blurred fat plane around the lesion
T3 or T4	Obliteration of the fat plane between the gastric tumour and adjacent organs (indeterminate)
T4	Gross infiltration of adjacent organs
N1–N3	Regional lymph nodes are considered involved when the short-axis diameter is > 6 mm for the perigastric lymph nodes and > 8 mm for the extraperigastric lymph nodes; other criteria for malignant involvement include a nearly round shape (longitudinal-transverse diameter ratio < 1.5), a fatty hilum that is eccentric or missing, and marked or heterogeneous enhancement

MAGNETIC RESONANCE IMAGING

A clinical role for magnetic resonance (MR) imaging of the gastrointestinal tract developed with the implementation of techniques to limit or eliminate bowel motion, remove high signal intensity of adjacent fat, increase the dynamic range of abdominal tissue signal intensities and artifacts. Specifically, fat suppression, breathhold gradient echo, single shot echo train T2-weighted techniques and intravenous gadolinium chelates all contributed to this endeavour. There is still a controversy, over which oral contrast agent, if any, is necessary for performing diagnostic studies (8).

The gastrointestinal tract magnetic resonance imaging remains still an evolving technology, several clinical applications have already emerged.

Images of the stomach are improved by gastric distension – water is usually sufficient. Presently MRI is important in diagnosing and imaging primary gastric tumours spread and intraperitoneal invasion. Many tumours are higher in signal than background stomach on T2-weighted images. The use of gadolinium increases leasions detections (14, 17).

The most commonly recommended imaging protocol includes: a) T1-weighted fat-suppressed spin-echo or breath hold, fat-suppressed, T1-weighted spoiled gradient echo (SGE) before and after intravenous gadolinium; b) precontrast breath-hold, T1-weighted SGE, and immediate postgadolinium T1-weighted SGE; c) T2-weighted (preferably fat suppressed T2-weighted) spin-echo in select cases (8, 9).

Breath-hold imaging is preferred whenever possible as it eliminates respiratory artifact. Traditionally, the long imaging times associated with conventional and even fast T2-weighted spin-echo sequences precluded their routine use when evaluating gastrointestinal pathology. Recently the implementation of half Fourier single shot turbo spin echo (HASTE) has made high-quality, T2-weighted imaging of the bowel possible. Clinical applications of HASTE are currently under investigation, however, advantages of the sequence include minimal susceptibility artifact (ideal for gas-filled bowel and in the presence of metal clips), minimal chemical shift artifact, and short acquisition time – 1 sec per section which obviates the need for suspended respiration (8, 9, 14).

The sensitivity of MRI is estimated on 97%, specificity on 79% and an overall accuracy on 92% for determining the presence or absence of extraserosal imaging (9).

CONCLUSIONS

The development of modern endoscopic diagnostics induces to search for more effective and accurate methods of radiological imaging of the stomach. However, one should not leave behind the conventional, well recognized methods.

Comparing the conventional radiological imaging with double contrast barium meal larger effectivenes of the latter was affirmed. Results of double contrast barium meal and endoscopy are comparable (16).

In our opinion double contrast barium meal should occupy a central place in diagnosing gastric pathology and constitute the basis for other methods.

In spite of the fact that double contrast barium meal is still regarded to be basic and initial to other diagnostic methods, such methods as EUSG, CT and MRI are becoming more and more important in diagnosing of not only neoplastic deseases.

The major advantage of gastric EUSG and MRI is the lack of exposure to X-rays, however, the application of the above mentioned methods is still beyond reach for the majority of patients and too expensive. These methods are not competitive but complementary and can constitute an excellent diagnostic means in hands of an experienced clinicist and radiologist.

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SUMMARY

The major aim of the review is presenting contemporary diagnostic methods applied in gastric imaging as well as their place in clinical treatment. The authors discuss both conventional and modern methods. Although the method of double contrast barium meal is still the most important in stomach diagnostics, the modern methods such as EUSG, CT and MRI are becoming more and more meaningful not only in evaluating gastric neoplastic pathological changes. All applied diagnostic procedures should not be competitive but complementary and constitute an excellent means in hands of an experienced clinicist and radiologist.

Współczesne metody obrazowania żołądka

Głównym celem pracy jest zaprezentowanie współczesnych metod diagnostycznych stosowanych w obrazowaniu żołądka oraz ich miejsca w postępowaniu klinicznym. Autorzy przedstawiają zarówno metody konwencjonalne, stosowane od wielu lat, jak również nowoczesne metody obrazowe. Jakkolwiek metoda podwójnego kontrastu zajmuje ciągle centralne miejsce w diagnostyce żołądka, to nowoczesne metody diagnostyczne, takie jak EUSG, CT i MRI, mają coraz bardziej istotne znaczenie w ocenie nie tylko nowotworowych zmian patologicznych żołądka. Wszystkie stosowane współcześnie procedury diagnostyczne nie powinny być konkurencyjne, ale komplementarne i stanowić doskonałe narzędzie w rękach doświadczonego klinicysty i radiologa.