dramatically with MDCT, enabling the detailed evaluation of local lesions and the detection of small metastases, even in ordinary axial images [14]. Moreover, workstations that are capable of processing the massive quantities of image data produced by MDCT have been developed, and the three-dimensional CT visualization of gastric lesions, which is called MDCT gastrography, has become straightforward. This trend is fairly flourishing in the diagnosis of colorectal cancer as MDCT colonography, which is considered to have a great potential of being a modality for colorectal cancer screening [15–17].

Three-Dimensional Visualization of the Stomach by MDCT Gastrography

To visualize gastric lesions in three dimensions using MDCT, it is necessary to distend the gastric lumen with a foaming agent (CO_2 gas). As a consequence of the contrast between the gas and the inner gastric surface, owing to the substantial difference in density, it is possible to effortlessly prepare 3D images of the inner gastric surface. MDCT gastrography employs two methods for visualization, virtual endoscopic views and 3D gas insufflation views, obtained by 3D processing of the CT image data (Fig. 8).

Evaluation of the Detectability of Gastric Carcinoma by MDCT Gastrography

In the 3-month period between March and June 2003, we evaluated 4-row MDCT (Aquilion; Toshiba Medical Systems, Tokyo, Japan) in 84 gastric carcinoma patients who underwent MDCT for preoperative staging. Each scan was performed with the standard abdominal scan parameter settings for preoperative staging using automatic exposure control [18]. We prepared virtual endoscopic and 3D gas insufflation views from the image data obtained for each patient by MDCT volume scans, and two radiologists prepared responses on the basis of all clinical data for each patient, including gastroscopic findings, and the detectability of gastric carcinoma was evaluated by consensus for each display method. Eighty-six gastric carcinoma lesions (44 early and 42 advanced lesions) were diagnosed in the 84 patients. The detectability by virtual endoscopic and 3D gas insufflation views by MDCT gastrography was 47.7% and 40.9%, respectively, for early lesions (Table 1), and 59.5% and 76.2% for advanced lesions (Table 2). Hence, the detectability was less than 50% for early lesions, but about 60%–70% for advanced lesions of gastric carcinoma [19]. Especially in early lesions, all protruded-type lesions could be recognized, while less than half of depressed-type lesions, which is a common type of early gastric carcinoma, were missed (Figs. 9, 10).

TABLE 1. Detectability for 44 early gastric carcinomas by multidetector row computed tomography (MDCT) gastrography

	Protruded type	Flat elevated type	Depressed type	Total
Virtual endoscopic views	100% (2/2)	50.0% (1/2)	45.0% (18/40)	47.7% (21/44)
Three-dimensional gas insufflation views	100% (2/2)	50.0% (1/2)	37.5% (15/40)	40.9% (18/44)

TABLE 2. Detectability for 42 advanced gastric cancers by MDCT gastrography

	Borrman I type	Borrman II type	Borrman III type	Borrman IV type	Total
Virtual endoscopic view	0% (0/1)	84.6% (11/13)	68.8% (11/16)	25.0% (3/12)	59.5% (25/42)
Three-dimensional gas insufflation view	0% (0/1)	76.9% (10/13)	68.8% (11/16)	91.7% (11/12)	76.2% (32/42)

MDCT gastrography is presently inadequate for the detection of gastric carcinoma and its potential for clinical application is low.

Potential for MDCT Gastrography in Preoperative Staging for Gastric Carcinoma

MDCT gastrography is simpler and less invasive than endoscopy and radiography, and permits evaluation of the stomach overall in an examination of short duration. Detection of early lesions is challenging, and although it therefore has low potential as a screening method, it is capable of detecting lesions that are advanced to a certain extent, and also of simultaneously detecting lesions in other organs of the abdomen. In preoperative staging, as for radiography, it is capable of objectively ascertaining the position and overall picture of the primary lesion, and of diagnosing the relations between the degree of extramural invasion and surrounding organs. With the axial images of MDCT, representing a quantum leap in resolution compared with normal CT, it was possible to also diagnose correctly lymph node metastasis. Because MDCT itself is an examination method required for the preoperative diagnosis of local spread or remote metastasis of gastric carcinoma, it is highly likely at present that it can partially replace the role of radiography or ultrasound endoscopy. As well, because the image data of MDCT is digitalized density information, it is possible to selectively visualize 3D information in a manner that is effective for diagnosis, and has a great potential of being a modality for computer-aided diagnosis [20]. By digitally combining the 3D view of the primary lesion and the 3D image data of diagnosed lymph node metastasis, it will be possible to provide surgeons with effective preoperative 3D views of gastric carcinoma (Fig. 11).

Conclusions

As a result of future advancements in image engineering and computer technology, digital radiographic systems and MDCT systems will continue to evolve, and it can be predicted that new diagnostic methods that utilize the advantages of digitalization in the radiological diagnosis of gastric carcinoma will also be developed. MDCT gastrography has little potential at present as a diagnostic method for the primary lesions of gastric carcinoma. However, with further advances in MDCT, higher-speed examinations, improved image quality, and optimization of exposure dose, it appears certain that MDCT gastrography will gradually replace radiography, endoscopy, and ultrasound endoscopy.

Acknowledgments. This work was supported by Grants for Scientific Research Expenses for Health and Welfare Programs and the Foundation for the Promotion of Cancer Research, and by the 3rd-term Comprehensive 10-year Strategy for Cancer Control from the Ministry of Health, Labor and Welfare.

References

1. Templeton FE (1964) X-ray examination of the stomach, rev edn. University of Chicago Press, Chicago
2. Kuru M (1966) X-ray diagnosis. In: Atlas of early gastric carcinoma of the stomach. Nakayama-Shoten, Tokyo, pp 219–223
3. Shirakabe H, Ichikwa H, Kumakura K, et al (1966) Atlas of X-ray diagnosis of early gastric cancer. Igaku Shoin, Tokyo
4. Ichikawa H (1993) X-ray diagnosis of early gastric cancer. Gastric cancer. Springer-Verlag, Tokyo, pp 232–245
5. Okumura T, Maruyama M (1993) A prospective study on advanced gastric cancer detection by mass screening. Gastric Cancer. Springer-Verlag, Tokyo, pp 263–277
6. Sonoda M, Takano M, Miyahara J, et al (1983) Computed radiography utilizing scanning laser stimulated luminescence. Radiology 148:833–838
7. Hillman BJ, Ovitt TW, Nudelman S, et al (1981) Digital video subtraction angiography of renal vascular abnormalities. Radiology 139:277–280
8. Iinuma G, Ushio K, Ishikawa T, et al (2001) Diagnosis of gastric cancers: comparison of conventional radiography with a 4 million-pixels charge-coupled device. Radiology 214: 497–502
9. Berland LL, Smith JK (1998) Multidetector-array CT: once again, technology creates new opportunities. Radiology 209:327–329
10. Hu H, He HD, Foley WD, Fox SH (2000) Four multidetector-row helical CT: image quality and volume coverage speed. Radiology 215:55–62
11. Metz CE, Goodenough DJ, Rossmann K (1973) Evaluation of receiver operating characteristic curve data in terms of information theory, with applications in radiography. Radiology 109:297–303
12. Botet JF, Lightdale CJ, Zauber AG, et al (1991) Preoperative staging of gastric cancer: comparison of endoscopic US and dynamic CT. Radiology 181:426–432
13. Habermann RC, Weiss F, Riecken R, et al (2004) Preoperative staging of gastric adenocarcinoma: comparison of helical CT and endoscopic US. Radiology 230:465–471
14. Ba-Ssalamah A, Prokop M, Uffmann M, et al (2003) Dedicated multidetector CT of the stomach: spectrum of diseases. *Radiographics* 181:426–432
15. Dachman A (2003) Atlas of virtual colonoscopy. Springer-Verlag, New York
16. Iannaccone R, Laghi A, Catalano C, et al (2003) Detection of colorectal lesions: lower-dose multi-detector row helical CT colonography compared with conventional colonoscopy. Radiology 229:775–781
17. Macari M, Bini EJ, Jacobs SL, et al (2004) Colorectal polyps and cancers in asymptomatic average-risk patients: evaluation with CT colonography. Radiology 230:629–636
18. Itoh S, Ikeda M, Mori Y, et al (2002) Lung: feasibility of a method for changing tube current during low-dose helical CT. Radiology 224:905–912
19. Iinuma G, Moriyama N (2004) Clinical potential of CT gastrography for visualization of gastric cancers. In: Recent advances in gastric cancers: the 17th International Symposium of Foundation for Promotion of Cancer Research, pp 37–38
20. Summers RM (2003) Road maps for advancement of radiologic computer-aided detection in the 21st century. *Radiology* 229:11–13

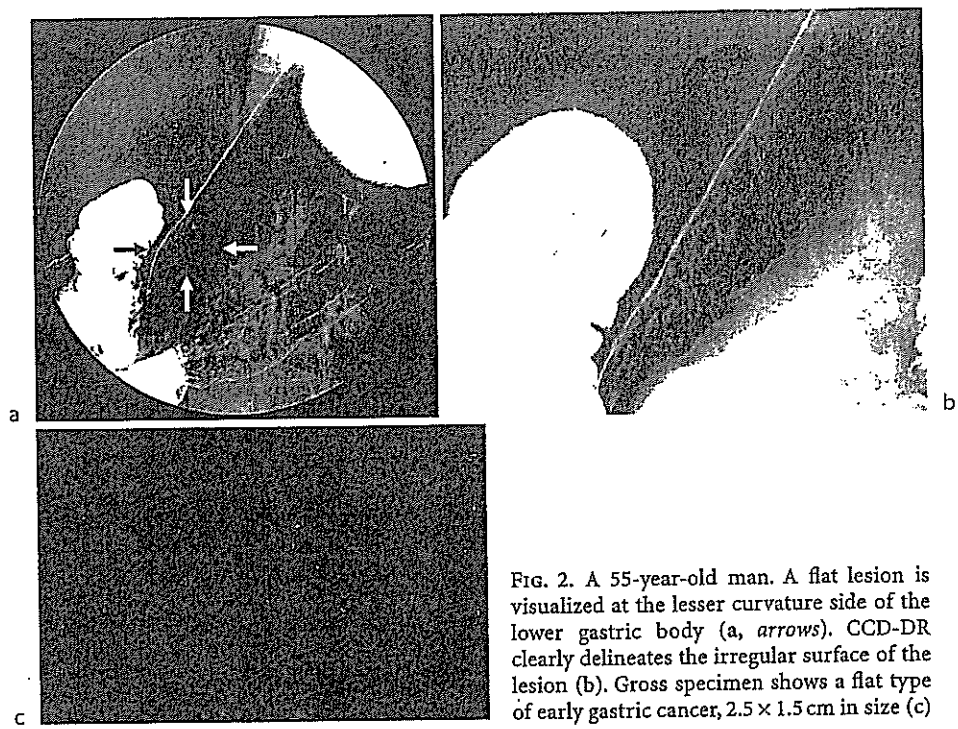

FIG. 2. A 55-year-old man. A flat lesion is visualized at the lesser curvature side of the lower gastric body (a, *arrows*). CCD-DR clearly delineates the irregular surface of the lesion (b). Gross specimen shows a flat type of early gastric cancer, 2.5 × 1.5 cm in size (c)

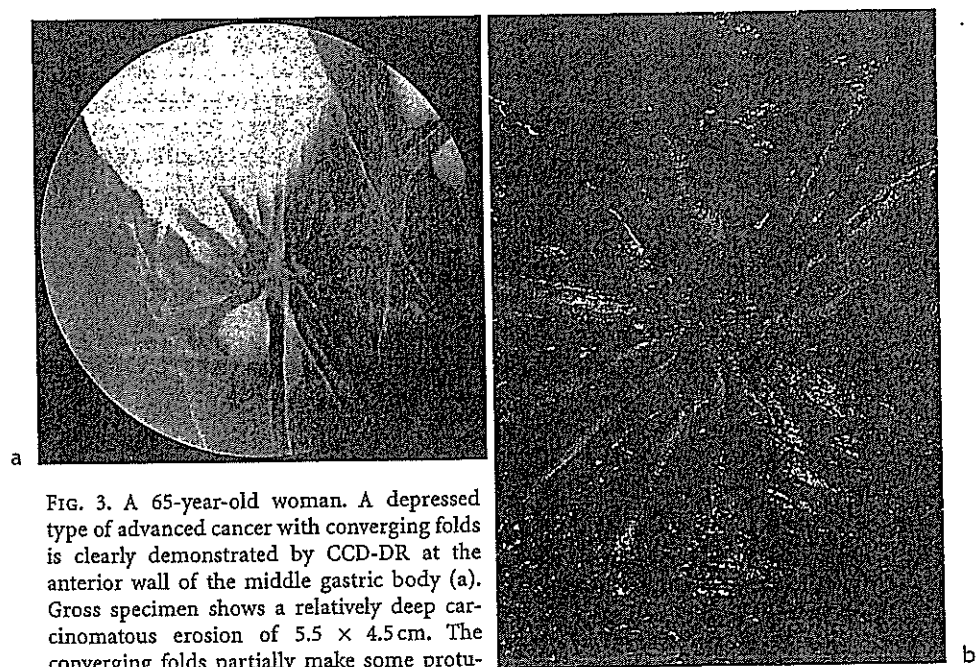

FIG. 3. A 65-year-old woman. A depressed type of advanced cancer with converging folds is clearly demonstrated by CCD-DR at the anterior wall of the middle gastric body (a). Gross specimen shows a relatively deep carcinomatous erosion of 5.5 × 4.5 cm. The converging folds partially make some protuberance at the margin of the lesion (b)

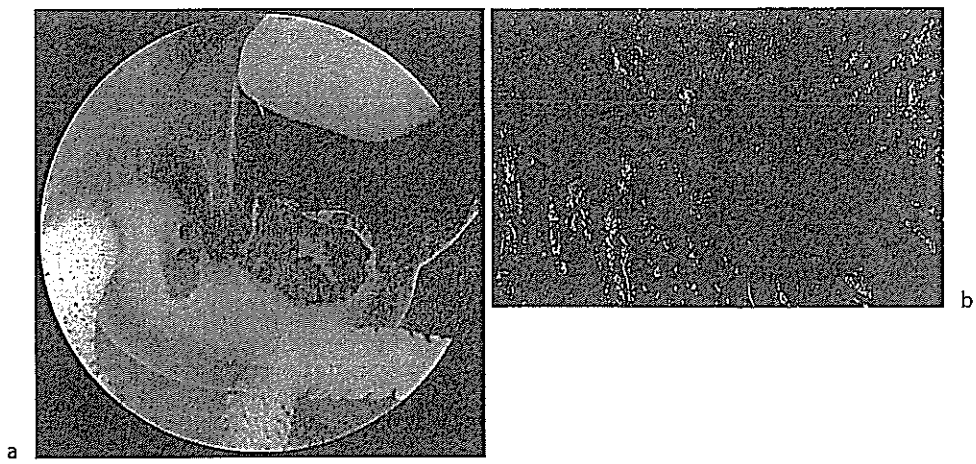

FIG. 4. A 70-year-old man. CCD-DR visualizes two gastric cancers at the posterior of the lower gastric body to the antrum (a). Gross specimen demonstrates a protruded advanced cancer with central ulceration measuring 4.0 cm and a protruded type of early cancer measuring 2.0 cm (b)

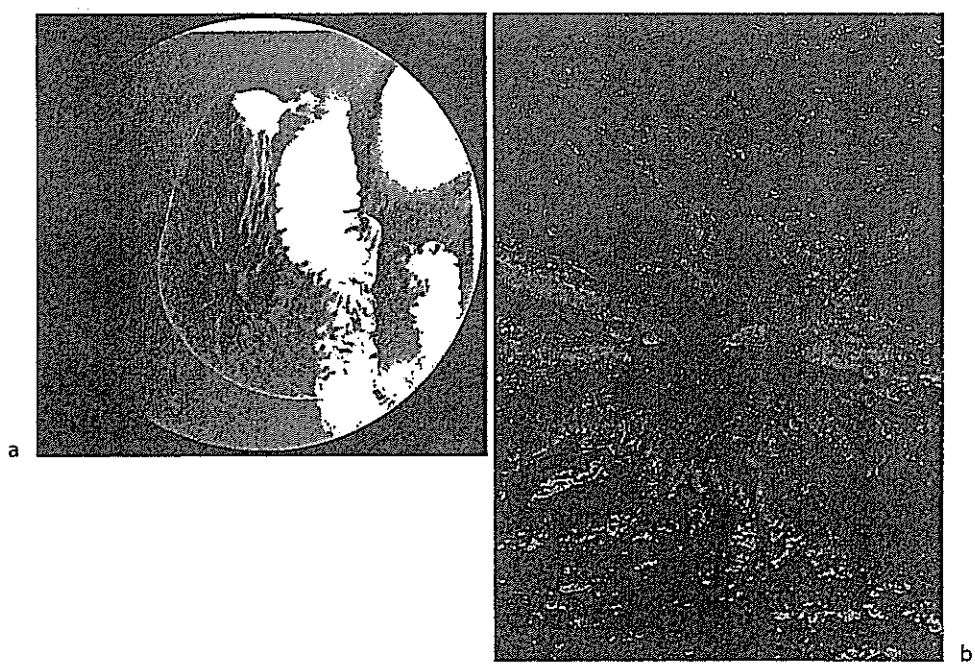

FIG. 5. A 55-year-old man. CCD-DR demonstrates a depressed type of gastric cancer at the posterior wall of the antrum (a). Gross specimen shows a depressed type of advanced cancer 5.0 × 4.5 cm in size (b)

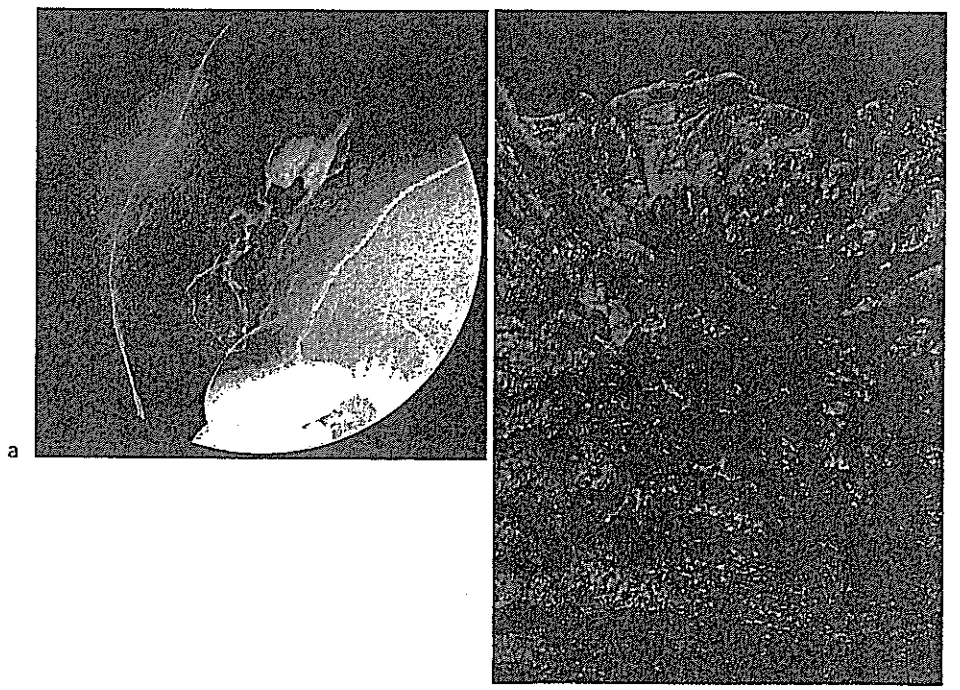

FIG. 6. A 71-year-old man. An advanced cancer is demonstrated by CCD-DR just below the cardia (a). Gross specimen shows an ulcerative type of advanced gastric cancer 6.0 cm in diameter (b)

FIG. 8. Two imaging modes of multidetector row computed tomography (MDCT) gastrography. a A representative virtual endoscopic view, resembling gastroscopic images. b A representative 3D gas insufflation view, resembling radiographic images

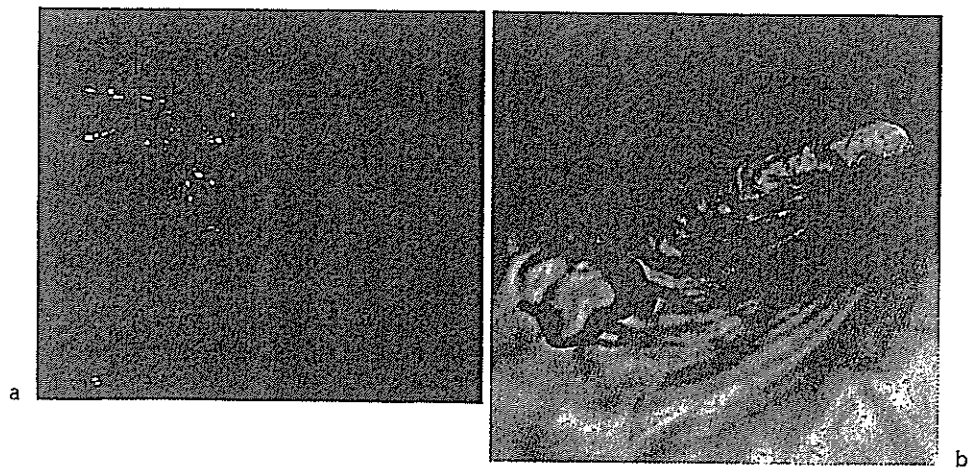

FIG. 9. A 63-year-old man. Conventional endoscopy demonstrates a protruded type of early gastric cancer 2 cm in size at the greater curvature side of the upper gastric body (a). The lesion is clearly visualized by virtual endoscopic view (b)

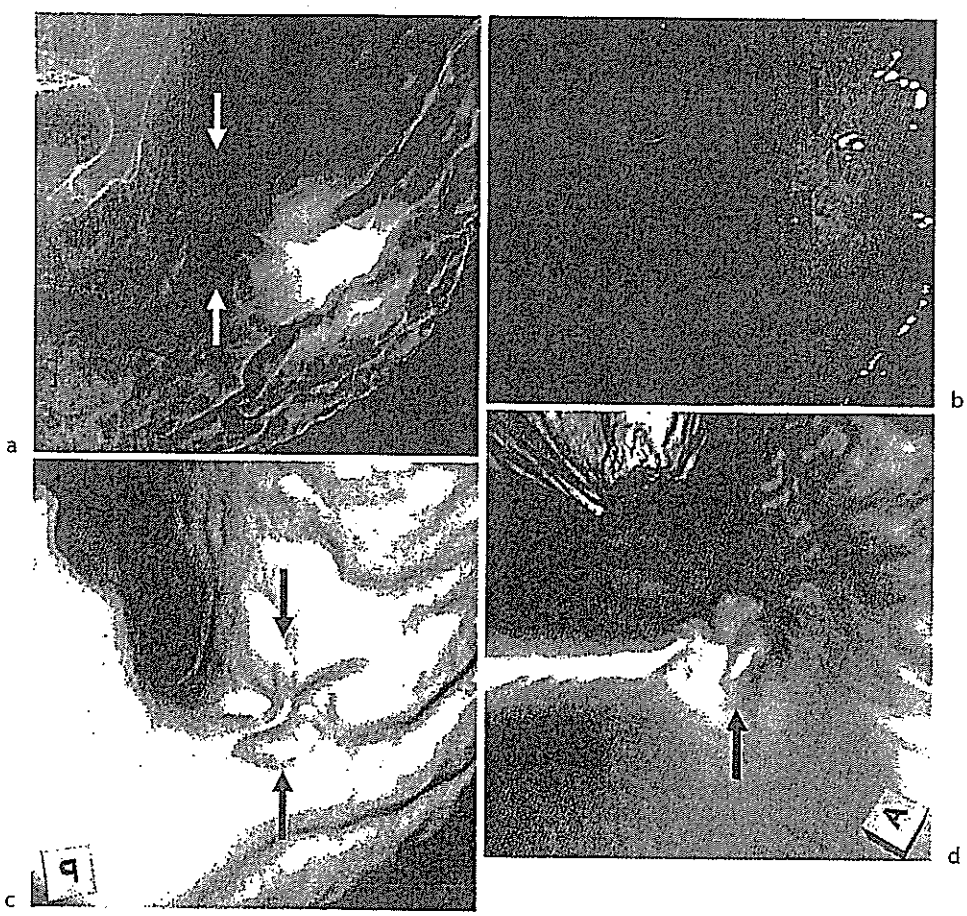

FIG. 10. A 33-year-old man. A small depressed type of early gastric cancer measuring 1.5 cm is identified at the posterior side of the gastric angle by gastric radiography and gastroscopy (*arrows* in a, b). The lesion can barely be recognized by virtual endoscopic and 3D views of MDCT gastrography (*arrows* in c, d)

FIG. 11. Three-dimensional imaging of a gastric cancer and lymph node metastases. The 3D view of the primary lesion (*arrow*) and the 3D image data of diagnosed lymph node metastases can be combined digitally to produce effective 3D views of gastric carcinoma in the pre-operative staging

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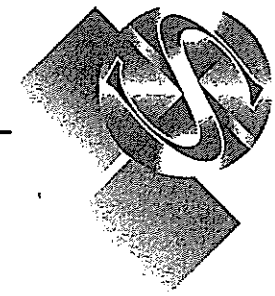

Surgical Resection of the Stomach with Lymph Node Dissection

Mitsuru Sasako, Takeo Fukagawa, Hitoshi Katai and Kateshi Sano

Aims

- To describe the techniques of radical lymph node clearance in gastric cancer surgery.
- To identify the aspects of surgery associated with significant morbidity.
- To define the use of pancreatic and splenic resection in gastric cancer surgery.

Type of Gastric Resection

Commonly Used Types of Resection

As gastrectomy is now rarely indicated for benign disease of the stomach, this chapter focusses on gastrectomy for gastric malignancies. For gastric cancers, several types of resection are commonly used. For proximal advanced tumours or large tumours, a total gastrectomy (TG) is usually used. For a distally located tumour which does not involve the proximal third of the stomach, a distal (DG) or distal subtotal gastrectomy (DSG) is the preferred type of gastric resection. In the 1980s, proximal gastrectomy (PG) was for a while abandoned because of the high incidence of reflux oesophagitis and in pursuit of radical surgery. However, with the identification of an increasing number of small T1/2 tumours located near the cardia, interest in the role of proximal gastrectomy has been renewed. For similar tumours in the middle of the stomach, pylorus preserving distal gastrectomy (PPG) is being undertaken in an attempt to improve quality of life after surgery [1].

Total Versus Subtotal Gastrectomy

The concept of total gastrectomy as the appropriate radical surgical management of gastric cancer was promoted by some enthusiasts in the West during the 1970s. This concept has been described as "gastrectomie totale en principe". In Japan, however, TG was carried out only when it was required to allow an R0 resection to be achieved while DG was carried out for many antral tumours, with satisfactory results. To establish the role of the extent of gastric resection, several trials have been carried out to evaluate TG in principle.

There have been two randomised controlled trials comparing TG with DG for antral tumours. In France between 1980 and 1985, 201 patients were randomized between TG and DSG to test if TG could increase 5-year survival rate from 30% after DSG to 50%. After excluding 32 ineligible cases, 84% of randomised patients were included in the analysis; no differences in postoperative morbidity and mortality or in 5-year survival rates were demonstrated [2]. A

similar trial was carried out in Italy enrolling 648 patients between 1982 and 1993 [3]. This trial was set up to test the equivalence of DSG and TG, i.e. DSG should show 5-year survival rates no worse than −10% of the results of TG (50%). There was no significant difference in postoperative death (1.2% after DSG and 2.3% after TG) and 5-year survival rate after DSG was better than after TG (65% versus 62%), confirming the equivalence of the two methods for antral tumours. A further trial has compared DSG with D1 nodal dissection versus TG with D3 dissection [4]. The sample size was small (55 patients) and hypothesis tested included both the extent of gastric resection and extent of lymphadenectomy; as a result the trial is difficult to evaluate. The results demonstrated no significant differences in outcome though the survival curve after DSG was better than after TG.

Theoretically, the oncological gain provided by TG over DSG lies in the reduction in the risk of positive resection margins, the removal of missed second primaries and increasing the extent of lymphatic clearance. The extent of nodal dissection increases the dissection of the left cardiac nodes, short gastric artery nodes, splenic hilum nodes and distal splenic artery nodes. The pattern of lymphatic spread in antral cancers would indicate that removal of these node groups is unlikely to improve outcome. The problem of positive margins is mainly due to inaccurate diagnosis of proximal extension of tumours. For cancers in the mid body on the greater curve, the risk of lymphatic involvement of the splenic hilar and distal splenic artery nodes might support a need for total gastrectomy. For such cases, negative sampling of the nodes at the root of the left gastroepiploic artery or the sentinel nodes may safely allow surgeons to avoid TG.

Indications for Proximal Gastrectomy (PG)

In 1970s, PG was abandoned for two reasons: a high incidence of local failure in the remnant stomach and frequent and severe reflux oesophagitis due to bile reflux when reconstruction was by oesophagogastrostomy. A dramatic increase in junctional tumours small cancers at the cardia, has been observed in the West. For small tumours located at the cardia as well as T1 tumours in the proximal third of the stomach, PG has been revived in both hemispheres during the 1990s. For T1 tumours of the proximal stomach, PG with extended D1 (D1 plus proximal splenic, coeliac and common hepatic artery nodes) is carried out, followed by a reconstruction with short segment jejunal interposition (modified Merendino's operation: Figure 25.1). For large tumours involving the cardia, because of intramural distal extension to the antrum and the significant incidence of nodal metastasis to the lower lesser curvature and infrapyloric nodes, a TG should be carried out. Harrison et al [5] claimed that TG is not necessary for proximal gastric cancer but the average size of the tumours treated by PG in their series was just 4 cm, much smaller than those treated by TG. Their method of reconstruction was traditional oesophagogastrostomy. As they did not evaluate the quality of life (QOL) of patients, especially in terms of reflux oesophagitis, their technique cannot be justified.

Pylorus Preserving Gastrectomy (PPG)

Due to the increasing recognition of early gastric cancer in Japan, several surgical techniques have been recently tested to reduce

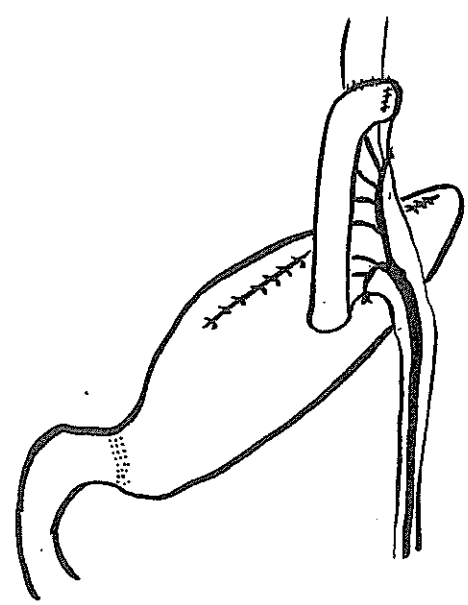

Figure 25.1. Modified Merendino's operation of proximal partial gastrectomy with jejunal interposition.

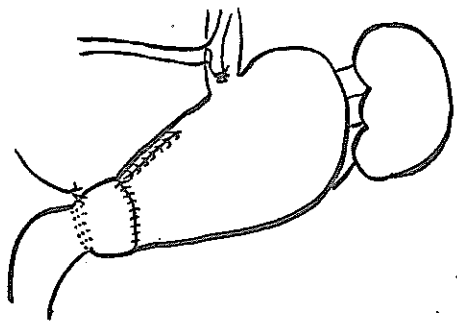

Figure 25.2. Pylorus preserving distal partial gastrectomy.

the incidence of postgastrectomy symptoms. Pylorus preserving gastrectomy is one of these options. This procedure was originally described by Maki as a surgical treatment for benign gastric ulcer [6]. By preserving the pylorus with a small part of the gastric antrum, rapid emptying of the stomach, causing the dumping syndrome, should be reduced. In the 1990s, this technique was introduced in patients with early gastric cancer of the middle part of the stomach [1]. There is now experience with hundreds of patients who have undergone this operation with satisfactory results, in terms of QOL and survival. The original method preserved 1.5 cm of the distal antrum but the preference now is to preserve at least 3 cm of the antrum for better gastric emptying (Figure 25.2).

Concept, Classification and Efficacy of Lymph Node Dissection for Gastric Carcinoma

Concept

The initial description of lymph node dissection for cancer treatment was in breast cancer by Halsted and the work was developed by Haagensen. The primary aim of this procedure is to avoid local failure in axillary lymph nodes. Originally all systemic metastasis was thought to occur via lymphatic spread. In this theory, called the Halstedian cancer model, cancer cells spread initially to the nearest nodes and then to farther nodes step by step, and eventually to various distant sites. Therefore the wider the nodal dissection, the better the survival that should be achieved. Local recurrence should be rare after adequate nodal dissection. However, cancer metastases occur not only via lymph stream but also primarily via the bloodstream and sometimes directly through the pleural or peritoneal cavity. In breast cancer, 20–30% of node-negative patients develop systemic recurrence [7]. Local recurrence sometimes occurs as a part of systemic recurrence in high grade tumours. Prognosis of patients with multiple nodal metastases worsens steeply as the number of metastatic nodes increases [8]. All these facts demonstrate that regional lymph nodes do not form an effective barrier to cancer dissemination. Several clinical trials have shown nodal dissection does not contribute to better survival for breast cancer and nodal metastasis is an indicator of poor prognosis. Nodal disease is indicative of a high risk of the presence of systemic disease (systemic disease model).

Unlike breast cancer, gastric cancer more closely follows the requisites for the original Halstedian model. Those having no or limited spread of nodal metastasis have a good prognosis if peritoneal seeding does not occur. Five-year survival rates of those having 4, 6, 8, 10 nodal metastases are 52.3%, 43.5%, 37.7%, 29.9%, respectively (unpublished data from National Cancer Center Hospital Tokyo). Systemic/distant metastases are quite rare in T1 and T2 tumours, whereas lymph node metastases are already frequent in these stages (Table 25.1) [9]. Thus in gastric cancer, nodal metastasis is the primary site of metastatic spread in most cases and systemic recurrence after curative operation in node-negative patients is rare. The commonest type of recurrence of advanced tumours is peritoneal seeding after formal nodal dissection [10]. However, recurrence after limited surgery occurs most frequently in the gastric bed and, with regional peritoneal seeding, accounts for over 90% of recurrences [11]. These differences between breast and gastric cancers might be explained by the following. First, the stomach is located in the portal venous system, with bloodborne metastases occurring most frequently via the portal vein to the liver rather than through the lympho-venous connection in the neck. Second,

the high intraluminal bacteria count is associated with an abundant lymphatic system including mucosa associated lymphoid tissue.

Most of the reported adjuvant chemotherapy trials have failed to prove any efficacy over surgery alone [12]. Recently a clinical trial comparing surgery plus radiochemotherapy versus surgery alone showed significantly better survival for the radiochemotherapy group [13]. In this study, 90% of the patients underwent either D0 or D1 lymph node dissection. This could be interpreted as showing that adjuvant chemotherapy may be effective when the local regional lymph node metastases are well controlled by radiotherapy. However, the survival results of the radiochemotherapy group in this study could not reach the level of the results achieved by D2 dissection alone. Therefore it is still uncertain whether D0/1 surgery plus radiochemotherapy can replace D2 dissection or not. In fact, retrospective analysis of the patients in this trial suggests that surgical undertreatment undermined survival [14].

Classification

Of the two commonly used classifications for gastric cancer, the Japanese classification [15] and the Union Internacional Contra la Cancrum (UICC) TNM classification, only the former includes a method for classification of the extent of lymph node dissection. The regional lymph nodes are topographically classified from the first to third tier nodes, according to the tumour location in the stomach. In general terms, perigastric nodes are usually classified as the first tier and lymph nodes in the suprapancreatic area with splenic hilum nodes comprise the second tier; nodes in the hepatoduodenal ligament, retropancreatic and para-aortic nodes are the third tier. Nodal dissection is defined as D1, D2 and D3. D0 is defined as excision which fails to remove all of the first tier nodes. D1 includes all first tier stations but not all of the second tier stations. D2 dissection includes all first and second tier stations but not all the third tier nodes. D3 means dissection including all first, second and third tier stations.

Efficacy

Many retrospective comparisons of lymph node dissection, D1 versus D2, have shown better survival for D2 (Table 25.2). The results of D1 have never reached the level of D2 dissection in terms of long-term survival according to stage. When the results of surgery are compared according to TNM stage, stage migration confounds comparisons. The wider the dissection, the more accurate the stage diagnosis, thus resulting in an increase in the number of cases at advanced stages and improvement of the results by stage in each category, stage migration. Therefore, for gastric cancer, the results of two groups who underwent different nodal dissection should be compared by T stage, which is not influenced by type of nodal dissection. Even in such comparisons, D2 always shows better results than D1. However, randomised controlled trials (RCTs) have never proven the superiority of D2 dissection over D1. Table 25.2 shows the results of these RCTs. Furthermore the two large-scale RCTs, the MRC trial [16] and the Dutch trial [17], showed significantly higher postoperative hospital mortality after D2 than D1. Initially these results we interpreted as pointing to an

Table 25.1. Metastases at the time of operation, 5-year survival, and haematogenous recurrence after resection in 4683 patients at National Cancer Center Hospital Tokyo, 1972–1991

Tumour depth	*n*	LN	Liver	Peritoneum	5Y SR (%)	Haematogenous rec.
pT1(m)	1063	3.3	0	0	93.3	2 (0.2%)
pT1(sm)	881	17.4	0.1	0	88.9	9 (1.0%)
pT2(mp)	436	46.7	1.1	0.5	81.3	26 (5.9%)
pT2(ss)	325	63.6	3.4	2.2	65.8	31 (9.5%)
pT3	1232	79.9	6.3	17.8	35.5	149 (12.1%)
pT4	724	89.7	15.5	41.6	10.1	106 (14.6%)
All	4683	47.8	4.5	11.5	60.3	318 (6.8%)

n, number; LN, lymph node; 5Y SR, 5-year survival rate, Rec, recurrence
Reproduced with permission from Mitsuru Sasako, What is reasonable treatment for gastric adenocarcinoma? J Gastroenteroc 2000; 35 [suppl XII]: 117.

inherently greater risk in D2 dissection. However, precise analyses of these trials and other reports elucidated surgical inexperience in those undertaking D2 dissection in these trials. Moreover, the only single arm study to assess the safety and effectiveness of D2 dissection, which was started after the publication of the results of MRC and Dutch trials, has demonstrated the safety of D2 dissection if done in high volume hospitals in the West. These trials provide important lessons around the importance of quality assurance in phase trials in surgery. The issue of timing of trial initiation has been raised, with suggestions that this should be determined on the basis of demonstration that individuals are near to the plateau of their learning curve of a difficult technique. Inexperience can produce large biases when comparing technically demanding surgical procedures.

Survival results of these trials in comparison to other studies are shown in Table 25.3. This table compares exclusively the results of D2 surgery, to avoid the stage migration effect. Sometimes, the results of the Dutch trial and MRC trials are interpreted as real evidence of non-superiority of the D2 dissection for gastric cancer. However, these are not trials set up to show the equality of D1 and D2 and with the factors pointed out above, the question is still unsolved. However, from the experience in these trials, it is obvious that D2 dissection should not be carried out by surgeons with insufficient experience of this technique and inexperienced surgeons should carry out this procedure strictly under the supervision of experienced surgeons.

Indications for Extended lymph Node Dissection (D2 Dissection)

Tumour Factors

This procedure should not be undertaken in incurable patients because of the increased morbidity associated with the technique. For T1

Table 25.2. D1 versus D2 5-year survival rates

Author	5-year survival rate D1	5-year survival rate D2	Reference
Pacelli F, et al	50.1	65.4	Br J Surg 1993;80:1153–6
Onate-Ocana LF, et al	35.1	64.0	Ann Surg Oncol 2000;7:210–17
De Manzoni G, et al	28	63	Br J Surg 1996;83:1604–7
Lee WJ, et al	34.8	41.5	World J Surg 1995;19:707–13
Sue-Ling H	18	45	Eur J Surg Oncol 1994;20:179–82
Gall FP, et al	43.6	51.8	Eur J Surg Oncol 1985;11:219–25

Table 25.3. D2 Surgery: trial results

Author	No. of patients	# patients/y/h	PO mortality	5-Year survival rates (%) Overall	IA	IB	II	IIIA	IIIB	IV
Siewert	803	14	5.0	NM	84	68	57	32	14	13
Pacelli	157	16	3.8	65	86	→	66	49	→	none
Sue-Ling	207	10	6	54	87	→	65	24	→	NM
Cuschieri	200	1	13.0	33	58	→	31	11	→	none
Bonenkamp	331	1	9.7	47	81	61	42	28	13	28
Sasako	2541	254	0.3	66	92	90	76	59	37	8
Jatzko	345	33	4.9	58	98	84	56	49	8	11
Hundahl *	32532	NM	NM	28	78	58	34	20	8	7

* Results of National Data Base, most cases are treated by D0/1, NM, not mentioned; none, no patient included; →, stage IB is included in stage IA and stage IIIB is included in stage IIIA; # patients/y/h, number of patients treated per year per hospital; PO mortality, postoperative mortality.

tumours, the risk of second tier node involvement is 5% and therefore in Western practice where the postoperative mortality is of the order of 5% in experienced centres, a D1 resection would be appropriate. This is dependent on the assumption that preoperative assessment of the depth of invasion is accurate.

For T4 tumours, a D2 dissection should be applied only when the entire tumour can be resected by the resection of neighbouring organs involved by the primary tumour. It remains unclear whether D2 dissection is of value in linitis plastica because of the frequency of recurrence in the peritoneal cavity despite an even higher incidence of nodal metastases in the second tiers than in other types. Indeed some authors claim that surgery is not indicated for this type of tumour. However, about 20% of cases of linitis plastica can be cured by D2 dissection combined with adjuvant chemotherapy when an R0 resection can be achieved. Although the recurrence rate in the peritoneum is high, cure without resection is not realistic and therefore D2 dissection remains an option in curable linitis plastica. As most tumours involve the greater curvature of the body and often the gastrosplenic ligament, splenectomy is usually required in addition.

Patient Factors

Postoperative hospital mortality after D2 dissection is over three times greater in aged patients and mortality after total gastrectomy is over five times greater in patients over 80 years old compared with those under 70. The results of the Dutch trial showed much higher mortality after D2 in aged patients. D2 total gastrectomy for aged patients should be carried out only in high volume hospitals by experienced surgeons.

As D2 dissection includes the meticulous dissection of lymph nodes in the suprapancreatic area, in obese patients the risks are increased as the pancreas is embedded in thick adipose tissue, hindering recognition of the border of the organ and increasing the risk of injury to either the parenchyma or the vessels to the pancreas.

Patients with impaired liver function are regarded as high risk for D2 dissection, especially cirrhotic patients. The development of massive and often uncontrollable ascites after D2 dissection occurs frequently and is often fatal. These patients have increased lymphatic flow surrounding the liver and D2 dissection disturbs the lymph circulation of these patients enormously.

After D2 dissection, fluid retention in both the abdominal and the retroperitoneal space is very great and maintenance of fluid balance following surgery can be difficult. Thus pneumonia or cardiac failure during the resorptive phase can occur and this phase requires intensive management. D2 should be undertaken with caution in those with impaired respiratory and cardiac function.

Combined Organ Resection for Lymphadenectomy

In the history of radical resection of cancers, combined resection of organs surrounding the primary tumour is based on the idea of en-bloc resection, which means complete resection of all the tissues through which draining lymph vessels pass. In gastric cancer surgery, complete bursectomy and omentectomy, pancreaticosplenectomy were based on the same idea. In en-bloc resection of the gastric bed with vascular pedicle, Appleby's operation, three-quarters of the pancreas distal to the portal vein, spleen, coeliac artery with its branches are resected en bloc [18]. Until 1980, pancreaticosplenectomy was a standard part of the D2 radical total gastrectomy. However, comparison of the survival benefit against the increased morbidity and mortality and the high incidence of diabetes mellitus led many surgeons to abandon pancreas resection. As a result, pancreas-preserving total gastrectomy became the standard in Japan during the 1990s [19]. It is now recognised that good survival rates can be achieved in node-positive patients without en-bloc resection of these neighbouring organs.

Two large clinical trials comparing D1 versus D2 showed that combined resection of spleen and pancreas largely accounted for the increased morbidity and mortality in a D2 dissection [16,17]. The remaining question is whether splenectomy alone increases the risk of operative mortality and whether it contributes to improved survival. Although in these trials splenectomy was associated with a worse prognosis, the close correlation with tumour site and histology (more proximal tumour and more

diffuse type) confounds unbiased comparison. Therefore, this can be answered only by an RCT comparing D2 TG with or without splenectomy. The Japanese Clinical Oncology Group started such a trial in 2002 aiming to accrue 500 patients to demonstrate non-inferiority of splenic preservation.

Combined resection of the entire or a part of organs invaded by the primary tumour is accepted as the only way to achieve R0 resection for some cases. For these T4 tumours, radiotherapy has not yet been proven to be as effective as surgical resection.

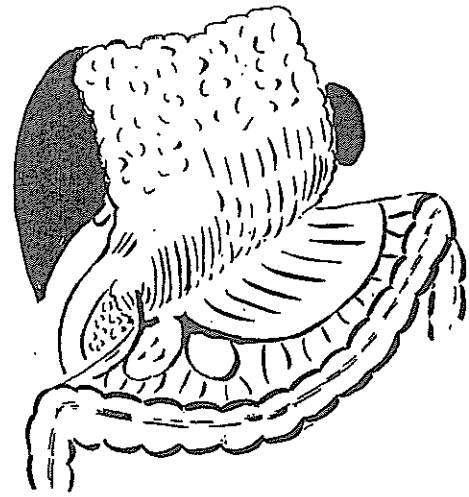

Figure 25.3. Elevation of greater omentum with anterior leaf of transverse mesocolon.

Techniques of D2 Dissection

Standard D2 TG: Pancreas Preserving TG

First an extensive mobilisation of the duodenum and the head of the pancreas is carried out to observe and palpate the para-aortic area. If there are nodes which are suspicious, sampling for frozen section should be carried out. If they are negative for cancer, radical D2 dissection is started. Complete omentectomy with resection of the anterior sheet of mesocolon is carried out (Figure 25.3). Many T3 tumours have lymphatic spread in the omentum, complete omentectomy remains a part of the standard D2 dissection. Similarly, T3 tumours adhering to the anterior sheet of the mesocolon and/or the pancreatic capsule may necessitate the resection of these structures and frequently turn out to be invading them. Complete bursectomy avoids tumour exposure in such cases. By carrying out this procedure, the accessory right colic vein is identified and followed proximally. It joins with the right gastroepiploic vein, forming Henle's surgical trunk which flows into the superior mesenteric vein (Figure 25.4). The right gastroepiploic vein is ligated and divided at its origin. For antral tumours, nodes on the superior mesenteric vein are also dissected. As the layer exposed by the bursectomy continues to the posterior aspect of the pancreas, the layer of the dissection should be changed to the anterior surface of the pancreas. Several vessels coming from behind the pancreas towards the anterior

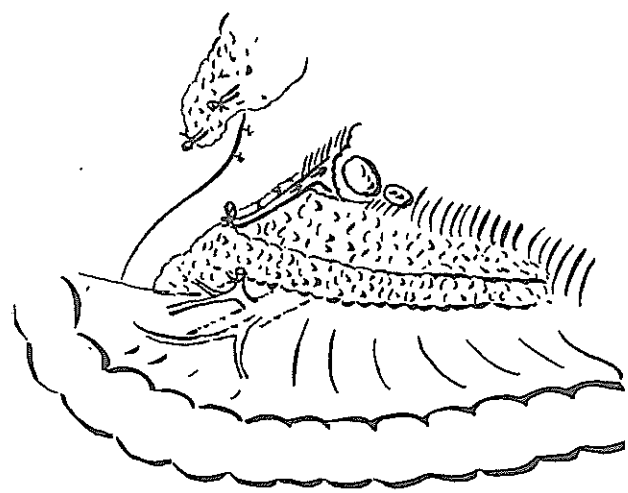

Figure 25.4. Division of right gastro-epiploic vein at Henley's trunk.

sheet of the mesocolon should be ligated at the inferior border of the pancreas.

The capsule of the pancreas is now dissected from the parenchyma in the middle part of the organ first, then toward the tail and the head, until the gastroduodenal artery is recognised. Following this artery, the root of the right gastroepiploic artery is found. After ligation and division of this artery at its origin, the stomach is lifted up to divide the back surface of the proximal duodenum from the pancreas and the gastroduodenal artery is followed cranially until the bifurcation of the common hepatic artery is recognized (Fig ure 25.4). The stomach

is laid back to the natural position and the lesser omentum is divided near the lateral segment of the liver from the left edge of the hepatoduodenal ligament to the oesophageal hiatus (Figure 25.5). This line is extended on the hepatoduodenal ligament to the left side of the common bile duct, where this incision is turned caudally towards the duodenum. Then the supraduodenal vessels, usually three or four in total, are ligated and divided close to the duodenal wall (Figure 25.6). This procedure makes a window above the duodenum, through which the gastroduodenal artery can be clearly seen. The connective tissue containing the lymph nodes in the hepatoduodenal ligament left of the common bile duct is dissected from right to left, from the duodenum towards the hepatic hilum along the gastroduodenal and then the hepatic artery. By doing so, the origin of the right gastric artery is easily identified, ligated and divided (Figure 25.6). Now the duodenum is divided a couple of centimetres from the pylorus by a linear type stapler. Pulling up the stomach from right to left and/or cranially, the suprapancreatic lymph nodes, common hepatic, coeliac, left gastric and splenic artery nodes are dissected, starting from the lymph nodes on the left side of the portal vein towards the nodes along the splenic artery. Downward traction of the pancreas by an assistant is extremely useful (Figure 25.7). During this procedure, the left gastric vein is encoun-

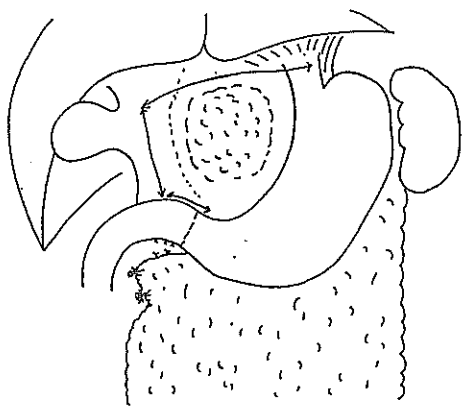

Figure 25.5. Line of division of the lesser omentum and duodenal clearance.

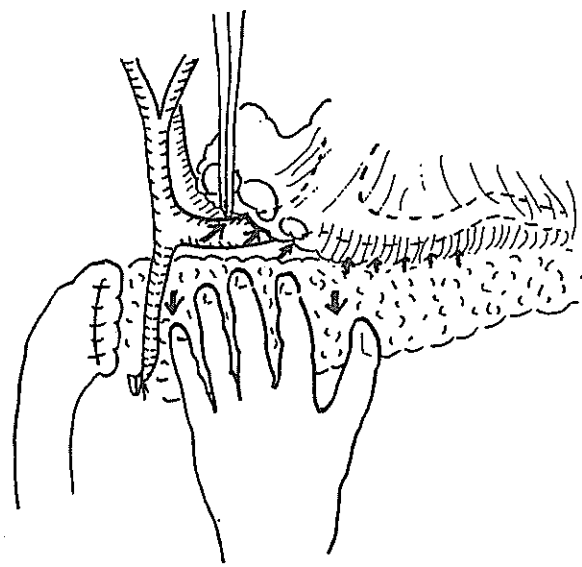

Figure 25.7. Clearance of suprapancreatic nodes along hepatic artery, celiac axis and splenic artery and peritoneum over pancreas. Note downward tension provided by assistant.

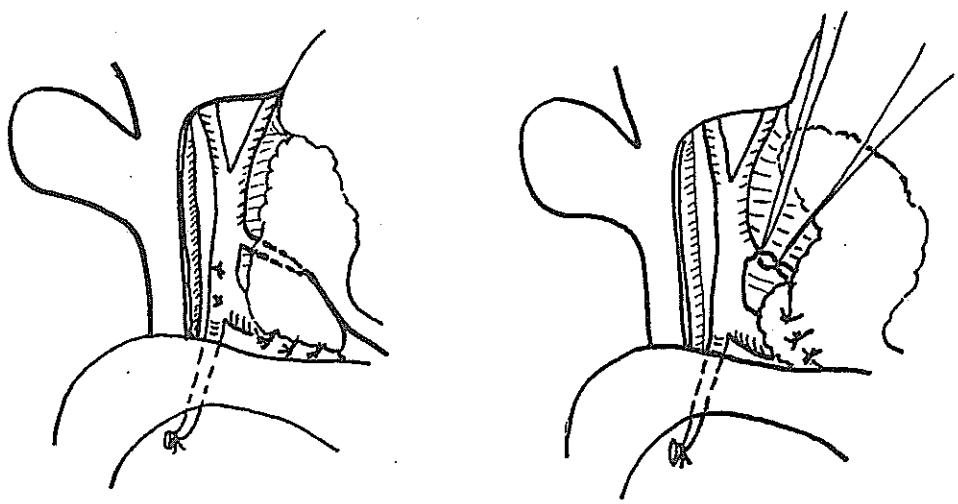

Figure 25.6. Identification and ligation of right gastric artery.

tered, most commonly behind the common hepatic artery (Figure 25.8). As a second frequent variation, this vein crosses over the common hepatic or splenic artery, flowing into the splenic vein. This vein is carefully found and then ligated and divided near its origin. The adipose tissue and thick nerve structures on the crus surrounding the oesophageal hiatus are divided from the crus, thus skeletonising the right side of coeliac artery and the origin of the left gastric artery. When the left hepatic artery is a branch of the left gastric artery, it should be preserved up to the origin of the hepatic artery in poor risk patients, to avoid necrosis of the lateral segment. Otherwise it should be ligated and divided at its origin.

The splenic artery nodes are dissected from the splenic artery around the origin of the posterior gastric artery (Figure 25.9). Near the origin of the posterior gastric artery, the great pancreatic artery branches off and comes into the pancreatic parenchyma. The splenic artery is now ligated and divided distal to the origin of the great pancreatic artery. In most cases, one of the large branches of the splenic vein appears on the anterior surface of the pancreatic tail. Then the pancreatic tail is mobilised completely from the retroperitoneum along Toldt's retropancreatic fascia. Traditionally the mobilisation started lateral to the spleen and the spleen is mobilised medially, pulling the spleen up with the operator's left hand. In this technique, the dissection on the left adrenal gland is carried out blindly, sometimes injuring the gland. To avoid this and the loss of the plane of dissection, it is better to mobilise the pancreatic body along Toldt's fascia at the upper border of the organ and continue towards the spleen. The lateral retroperitoneum is incised last (Fig 25.10). When the pancreas left of the coeliac artery is completely mobilised, the lymph nodes on the posterior surface of the pancreatic tail are dissected carefully, preserving the branches of splenic vein to the pancreas (Figure 25.11). All the branches from splenic vein to the stomach are carefully ligated and divided. After the pancreatic tail vein is preserved, the trunk of the splenic vein is ligated and divided. The vein commonly divides before the tip of the pancreatic tail and the branches are ligated separately. Now the pancreatic tail is naked and separated completely from the stomach and the spleen (Figure 25.12). The last step of the procedure is to dissect the left side of the oesophageal hiatus

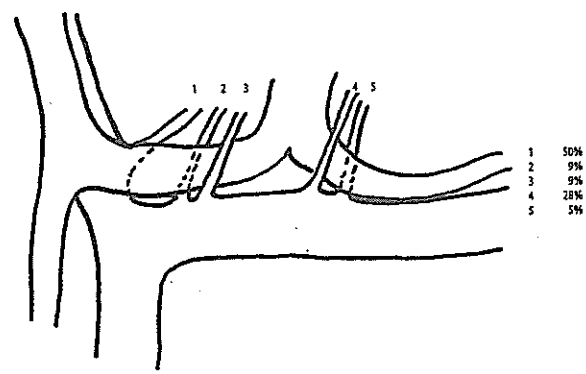

Figure 25.8. Variations in anatomy of left gastric vein.

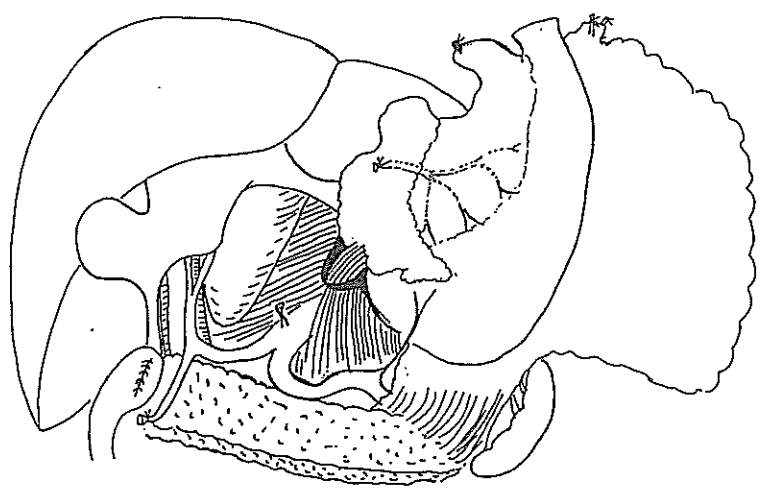

Figure 25.9. Origin of posterior gastric artery, defining point of division of splenic artery.

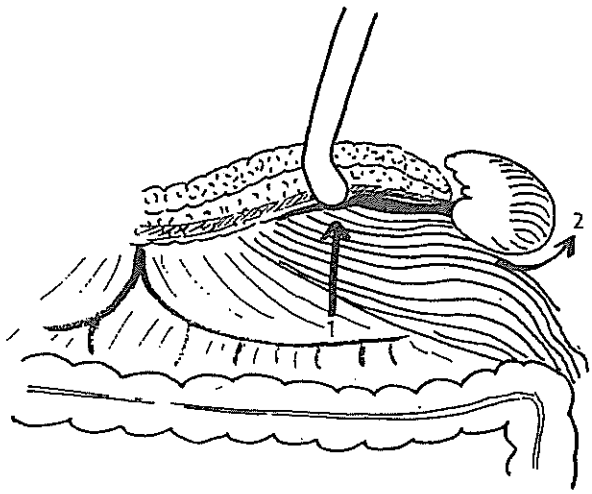

Figure 25.10. Mobilisation of the pancreatic tail along Todt's fascia.

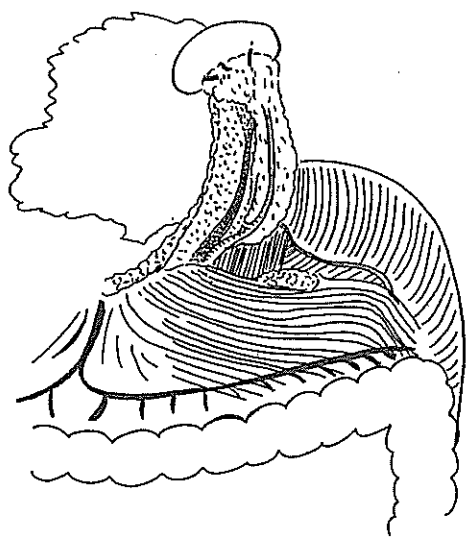

Figure 25.11. Dissection of pancreas to region of celiac axis preserving venous drainage to pancreas.

by ligating the oesophagocardiac branch of the inferior phrenic vessels. Both vagal nerves are divided 2–3 cm proximal to the cardia and the abdominal oesophagus is transected. An alternative technique is to divide the oesophagus as the primary step and the splenic artery nodes are dissected by pulling the entire specimen downward.

There are several methods of reconstruction of the digestive tract after total gastrectomy. The commonest and simplest method is Roux-en-Y reconstruction. Another commonly used

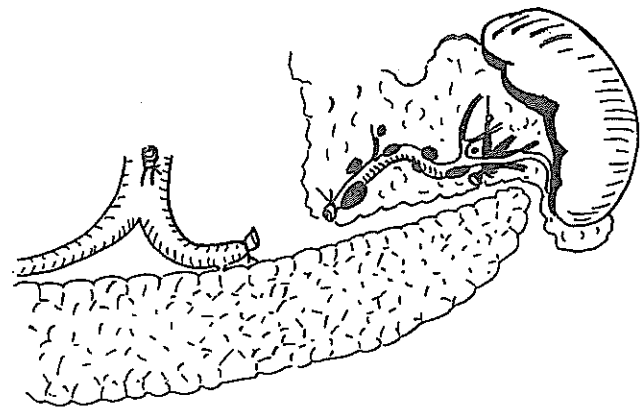

Figure 25.12. Separation of distal splenic artery and spleen following division of branches from splenic vein to spleen and stomach.

method is jejunal interposition. Reconstruction using a pouch in conjunction with either method has been trialled but the advantage of these techniques over simple reconstruction is not clear. The oeophagojejunal anastomosis should be end to side and can be carried out using a circular stapler, with a leakage rate of 1–2% [20]. In cases where the anastomosis lies in the mediastinum, it may be necessary to divide one or two jejunal arteries from their trunk, keeping the peripheral arcade intact, to allow the jejunum to reach the anastomotic site without tension.

TG with PS

In a conventional D2 total gastrectomy with pancreaticosplenectomy, the pancreas is transected near the coeliac artery. The indications for a combined resection are a T4 tumour invading the pancreas, bulky nodal metastases in the suprapancreatic area or metastatic nodes invading the pancreas. In these cases, the pancreas is transected adjacent to the portal vein. When the pancreas is resected, the splenic artery is ligated and divided at its origin, preserving the common hepatic artery, and then the splenic vein is divided at the resection line of the pancreatic parenchyma or its origin from the portal vein. The remainder of the procedure is the same as pancreas preserving total gastrectomy.

Standard Distal Gastrectomy

Most of the procedure is as described for total gastrectomy. A crucial issue in the procedure of

distal subtotal gastrectomy is splenectomy. In the MRC and the Dutch trials, some surgeons carried out splenectomy in distal gastrectomy. In D2 dissection, where the left gastric artery is ligated and divided at its origin, the blood supply to the remnant stomach is provided by the short gastric vessels, posterior gastric vessels and cardio-oesophageal branch from the inferior phrenic vessels. As the latter two are sometimes absent, the short gastric vessels are crucial to the viability of the remnant. Splenectomy should be avoided in distal gastrectomy, despite many textbooks of surgical technique showing all short gastric vessels ligated in distal subtotal gastrectomy. Mortality after D2 distal gastrectomy with splenectomy was 50% in the Dutch trial.

Another technical point is the dissection of right cardiac nodes in distal gastrectomy. These nodes are embedded in adipose tissue loosely attached to the gastric wall and easily divided from the wall without breaking the membrane enveloping the adipose tissue. All small branches to the gastric wall are divided, anterior and posterior branches separately (Figure 25.13) together with numerous small vagal fibres. The last technical point is how to dissect the greater curvature nodes along the left gastroepiploic vessels. These vessels are most commonly the last branch of the splenic vessels. At the tip of the pancreas, near the splenic hilum, they arise from the inferior border of the organ running toward the stomach in the splenogastric ligament (Fig 25.14). Unlike the right gastroepiploic artery and vein, these vessels do not have a main trunk but three or four long branches in a palm-like shape. Sometimes, the inferior polar branch of the splenic artery comes from the gastroepiploic artery. In such cases, ligation of the left gastroepiploic artery renders a small part of the spleen ischemic but rarely causes any serious problems.

PPG

PPG was originally advocated by Maki [6] as surgical treatment for benign gastric ulcer, to avoid dumping syndrome, the most important long-term sequela of distal gastrectomy. As a result of the remarkable increase in early gastric cancer in Japan, this technique was introduced in the 1990s for early gastric cancers located near the incisura. A 3 cm antral remnant is preserved and anastomosed to the proximal gastric remnant close to the greater curvature. By preserving the hepatic branch of the anterior vagal trunk and subsequently the pyloric branch, gastric emptying function is well preserved. As a result, the suprapyloric nodes are not systematically dissected in this operation as early gastric cancers in the middle part of the stomach have a less than 1% risk of these nodes being involved. Other nodal stations in D2 distal gastrectomy can be dissected as usual. Precise evaluation of this technique in terms of both

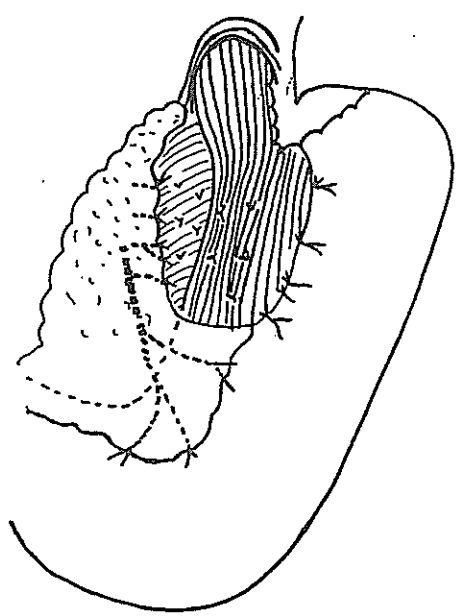

Figure 25.13. Clearance of right cardia nodes in distal gastric resection.

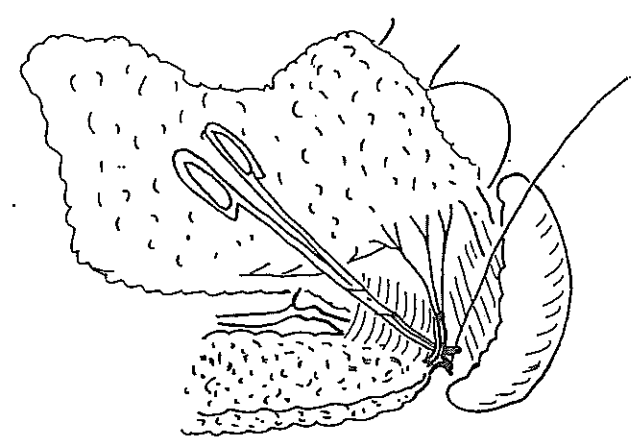

Figure 25.14. Identification of left gastro-epiploic vessels, usually last branch of splenic vessels.

6. Maki T, Shiratori T, Hatafuki T, Suganuma K. Pylorus-preserving gastrectomy as an improved operation for gastric ulcer. Surgery 1967;61:838–45.
7. Johnson H, Masood S, Belluco C et al. Prognostic factors in node-negative breast cancer. Arch Surg 1992;127: 1386–91.
8. Yeh IT, Fowble B, Viglione MJ et al. Pathologic assessment and pathologic factors in operable breast cancer. In: Breast cancer treatment.
9. Sasako M. What is reasonable treatment for gastric adenocarcinoma? J Gastroenterol 2000;35(suppl XII): 116–20.
10. Katai H, Maruyama K, Sasako M et al. Mode of recurrence after gastric cancer surgery. Dig Surg 1994; 11:99–103.
11. Gunderson LL, Sosin H. Adenocarcinoma of the stomach: Areas of failure in a re-operation series (second or symptomatic look) clinicopathological correlation and implications for adjuvant therapy. Int J Radiat Oncol Biol Phys 1982;8:1–11.
12. Hermans J, Bonenkamp JJ, Boon MC et al. Adjuvant therapy after curative resection for gastric cancer: meta-analysis of randomized trials. J Clin Oncol 1993;11:1441–7.
13. Macdonald JS, Smalley SR, Benedetti J et al. Chemoradiotherapy after surgery compared with surgery alone for adenocarcinoma of the stomach or gastroesophageal junction. N Engl J Med 2001;345:725–30.
14. Hundahl SA, Macdonald JS, Benedetti J, Fitzsimmons T, for the Southwest Oncology Group and the Gastric Intergroup. Surgical treatment variation in a prospective, randomized trial of chemoradotherapy in gastric cancer: The effect of undertreatment. Ann Surg Oncol 2002;9:278–86.
15. Japanese Gastric Cancer Association. Japanese classification of gastric carcinoma, first English edn. Tokyo: Kanehara, 1995.
16. Cuschieri A, Fayers P, Fielding J et al for the Surgical Cooperative Group. Postoperative morbidity and mortality after D1 and D2 resections for gastric cancer: preliminary results of the MRC randomized controlled surgical trial. Lancet 1996;347:995–9.
17. Bonenkamp JJ, Hermans J, Sasako M, van De Velde CJH, for the Dutch Gastric Cancer Group. Extended lymph-node dissection for gastric cancer. N Engl J Med 1999;340:908–14.
18. Appleby LH. The celiac axis in the expansion of the operation for gastric carcinoma. Cancer 1953;6:704–7.
19. Maruyama K, Sasako M, Kinoshita T et al. World J Surg 1995;19:532–6.
20. Nomura S, Sasako M, Katai H et al. Decreasing complication rates with stapled esophagojejunostomy following a learning curve. Gastric Cancer 2000;3:97–101.
21. Sasako M, Katai H, Sano T, Maruyama K. Management of complications after gastrectomy with extended lymphadenectomy. Surg Oncol 2000;9:31–4.