Feasibility of Pylorus-Preserving Gastrectomy With a Wider Scope of Lymphadenectomy

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Objective: To demonstrate the feasibility and safety of pylorus-preserving gastrectomy (PPG) accompanied by complete suprapyloric and infrapyloric lymph node dissection.

Design: Retrospective review.

Setting: A university hospital in Japan.

Patients: Fifteen patients underwent PPG, and 28 patients underwent conventional distal gastrectomy (CDG) with Billroth I anastomosis. All patients had early gastric cancer, with either limited invasion in the mucosal layer or invasion into the submucosal layer.

Interventions: In the PPG procedure, the distal part of the stomach was resected while retaining a 1.5-cm pyloric cuff. The right gastroepiploic artery, the right gastric artery, and hepatic and pyloric branches of the vagus nerve were divided, and the infrapyloric artery was preserved. A modified D1 or D2 lymphadenectomy accompanied the PPG.

Main Outcome Measures: Patients undergoing the PPG and CDG procedures were assessed 1 year after their surgical procedure. Changes in body weight, serum total protein levels, and serum albumin levels, the incidence of dumping syndromes, and endoscopic findings in the gastric remnant were compared between the 2 groups.

Results: Weight loss was significantly less in the PPG group than in the CDG group ($P = .02$). The incidences of early dumping syndromes, especially vasomotor symptoms, were significantly lower in the PPG group than in the CDG group ($P = .03$ and $P = .02$, respectively). The pyloric sphincter function was preserved, and there was no anastomotic leakage in the PPG group.

Conclusions: The PPG procedure with complete D2 lymphadenectomy can be performed safely with a low incidence of major complications and a better postoperative outcome than the CDG procedure. The PPG procedure can be recommended for the treatment of early gastric cancer with broader indications.

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DUMPING syndromes and alkaline reflux gastritis comprise most of the postgastrectomy syndromes, and these disorders sometimes result in patients having restricted food intake, rapid weight loss, and malnutrition, as well as the development of gastric remnant cancer. For the treatment of early gastric cancer, efforts to minimize postoperative morbidity and mortality and to obtain a better quality of life following surgical therapy have increased because the survival rates of early gastric cancer following radical gastrectomy have already reached around 95%. On this basis, several types of limited surgical interventions for early gastric cancer have been developed in Japan without decreasing the survival rates. Pylorus-preserving gastrectomy (PPG), which was originally applied to the treatment of peptic ulcer with satisfactory results, has become one of the treatment modalities of limited surgical therapy for early gastric cancer to avoid the dumping syndromes and bile fluid regurgitation. Although the previously reported PPG procedures were demonstrated to have postoperative functional benefits, incomplete suprapyloric lymph node dissection to preserve the right gastric and pyloric branch of the vagus nerve by these procedures resulted in limited indications for the PPG. Recent investigations showing that the right gastric artery and the pyloric branch of the vagus nerve could be divided without affecting the blood flow or motility of the pylorus suggest the possibility of a complete perigastric lymphadenectomy with PPG.
PATIENTS AND METHODS

PATIENTS AND TUMOR CHARACTERISTICS

Between January 6, 1993, and December 19, 1995, 44 patients with early gastric cancer underwent surgical intervention with curative intent in the Third Department of Surgery, University of Tokyo Faculty of Medicine, Tokyo, Japan. (The term early gastric cancer will be defined later.) Among the 44 patients, 16 underwent PPG and 28 underwent CDG with Billroth I reconstruction. If the distance between the distal margin of the gastric cancer and pyloric ring was confirmed to be more than 3.5 cm, the patients underwent PPG. The CDG procedure was performed if the patients did not meet the previously mentioned criteria, if intramucosal spread of the cancer cells was highly probable, or if other associated lesions such as gastric or duodenal ulcer scar were observed. One patient in the PPG group was excluded from this study because he died of causes other than gastric cancer within 1 year after the surgical procedure.

For the clinicopathologic findings of the gastric cancer, we used the TNM classification to describe the depth of invasion and lymph node or distant metastases. In this study, suprapyloric and infrapyloric lymph nodes were classified as N1. The depth of cancer invasion of the resected specimen was diagnosed by postoperative histological examinations (pT classification), and early gastric cancer was classified as pT1 cancer. Furthermore, pT1 cancer was subdivided into limited invasion in the mucosal layer (mucosal gastric cancer) and invasion into the submucosal layer (submucosal gastric cancer). The maximum tumor diameter was evaluated macroscopically. Other characteristics, such as the location of tumor and gross description, were divided according to the Japanese classification. The location of tumor was classified as upper, middle, or lower third. Gross type was subdivided into superficial elevated (Ia), flat (IIb), superficial depressed (IIC), a shallow depression with ulceration (IIC+III), and a shallow depression and elevation type (IIC+Ia or IIC+Ila). Histological types were classified as low grade or high grade according to criteria of the World Health Organization. The low-grade type consisted of moderately or well-differentiated cancer or signet ring cell cancer.

SURGICAL PROCEDURE

For patients in both the PPG and the CDG groups, the scope of lymphadenectomy was performed as described previously. In brief, it was classified as D1 if the dissection included only lymph nodes of N1 and as D2 if it included lymph nodes of both N1 and N2. Lymphadenectomy around the left gastric artery was combined with D1—and classified as a modified D1—if the cancer was preoperatively diagnosed as a mucosal gastric cancer. If the cancer was preoperatively diagnosed as a submucosal gastric cancer, a D2 lymphadenectomy was performed. However, postoperative evaluation of the PPG procedure with suprapyloric lymph node dissection has not been undertaken. This study demonstrates that a PPG procedure accompanied by suprapyloric lymph node dissection is superior to conventional distal gastrectomy (CDG) with Billroth I reconstruction and indicates that this procedure can be performed without any major complications. These findings also imply that the complete D2 lymphadenectomy can be performed with PPG and that wider application of PPG for early gastric cancer is feasible. In the D2 lymphadenectomy, perigastric lymph nodes and lymph nodes around the common hepatic, celiac, and left gastric arteries were dissected.

The PPG procedure was performed as described previously. The distal part of the stomach was resected while retaining a 1.5-cm pyloric cuff. The infrapyloric artery, most of which originates from the gastroduodenal artery, was preserved during the operation to maintain the blood flow around the anastomotic lesion. The right gastroepiploic artery was divided with preservation of the infrapyloric artery. Our technical modification consisted of dividing the right gastric artery at its origin and dividing the pyloric branches of the vagus nerve. By these procedures, the suprapyloric and infrapyloric lymph nodes could be completely dissected. The proximal margin of the stomach was transected at the same line as for CDG. The reconstruction was performed by methods similar to the Billroth I procedure with gastrogastrostomy using layerto-layer sutures.

POSTOPERATIVE FOLLOW-UP

Early postoperative complications were recorded in both groups. Postoperative assessments of PPG and CDG were performed 1 year after the surgical procedure by routine laboratory examinations, a questionnaire, an interview at an outpatient clinic, and an upper gastrointestinal tract endoscopy.

All patients completed their own questionnaire. Body weight, serum total protein concentration, and serum albumin concentration, each measured before and 1 year after the operation, were used for nutritional indicators. The ratio of body weight increase was defined as the body weight increase in 1 year divided by the preoperative body weight. Each patient was sent a questionnaire asking about symptoms of early (within 30 minutes after food intake) and late (3 hours after food intake) dumping syndromes. The questionnaire listed the symptoms of early and late dumping syndromes to allow patients to choose all the symptoms that they were having. Early gastrointestinal dumping symptoms included abdominal fullness, crampy abdominal pain, nausea, vomiting, and explosive diarrhea. Early vasmotor dumping symptoms included diaphoresis, weakness, dizziness, flushing, and palpitations. Late dumping symptoms included those similar to early vasmotor dumping symptoms. The findings of esophagitis, gastritis, and bile fluid regurgitation in the remnant stomach through the upper gastrointestinal tract endoscopy were recorded. Patients’ survival rates were confirmed at the time of this study.

STATISTICAL ANALYSIS

The Student t test was used to test the equality between the 2 means of variables of the treatment groups. The Fisher exact test or χ² test was used to test the independence between the 2 groups. Differences were considered significant at P<.05.

Data are presented as mean ± SD.
Patient and Tumor Characteristics*  

<table>
<thead>
<tr>
<th>Characteristics†</th>
<th>PPG Group (n = 15)</th>
<th>CDG Group (n = 28)</th>
<th>P</th>
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<tr>
<td>Age, mean ± SD, y</td>
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<td>58.0 ± 17.1</td>
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<tr>
<td>Sex</td>
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<td>Female</td>
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</tr>
<tr>
<td></td>
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<td>21 (75)</td>
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</tr>
<tr>
<td></td>
<td>4 (27)</td>
<td>7 (25)</td>
<td>.31</td>
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<td>Iib</td>
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<tr>
<td></td>
<td>3 (20)</td>
<td>1 (7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Iib</td>
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</tr>
<tr>
<td></td>
<td>Iic</td>
<td>7 (47)</td>
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<tr>
<td></td>
<td>Iia+Iic</td>
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</tr>
<tr>
<td></td>
<td>Iic+III</td>
<td>4 (27)</td>
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<td>Lower third</td>
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</tr>
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</tr>
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<td></td>
<td>1 (4)</td>
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<td>Depth of invasion</td>
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<td>Submucosal layer</td>
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<tr>
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<td>5 (33)</td>
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<td>27 (96)</td>
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* Data are given as number (percentage) of patients unless otherwise indicated. PPG indicates pylorus-preserving gastrectomy; CDG, conventional distal gastrectomy. Because of rounding, some percentages add up to more than 100.
† Tumor characteristics are classified according to the Japanese classification.

RESULTS

CLINICOPATHOLOGIC FINDINGS

The Table shows the clinicopathologic findings of the gastric cancer in both treatment groups. A significant difference was found in gross (P = .04) and histological types of cancer (P < .05). In contrast, age, sex, location of cancer, depth of invasion, and lymph node involvement were not found to be significant. The means of the total number of dissected lymph nodes were 27.3 ± 15.3 in the PPG group and 26.1 ± 12.8 in the CDG group (P = .77). One patient in the CDG group had perigastric lymph node involvement (pN1). This patient had the Ila + Iic type of gastric cancer with submucosal invasion.

EARLY POSTOPERATIVE COMPLICATIONS AND PATIENT SURVIVAL

The postoperative complications in the PPG group were acute pancreatitis in 1 patient and subphrenic abscess in another. Postoperative complications in the CDG group were wound infection in 2 patients, stomal stenosis in 2 patients, and acute pancreatitis in 1 patient. The differences in the postoperative complication rates between the 2 groups were not significant (P = .47). All patients with complications recovered with conservative therapy.

No postoperative death occurred, and no patients died of recurrence in either treatment group.

NUTRITIONAL STATE

The mean ratio of body weight increase in the PPG group (−4.1% ± 7.5%) was significantly higher (P = .02) than that in the CDG group (−10.3% ± 7.8%) (Figure 1). The mean serum total protein concentrations in the PPG group (73 ± 3 g/L) had a tendency to be higher than those in the CDG group (71 ± 4 g/L) 1 year after the operation, but the differences were not significant (P = .09). There was also no significant difference in preoperative mean serum total protein concentrations between the 2 groups (Figure 2). The mean serum albumin levels in the PPG group (42 ± 2 g/L) and in the CDG group (42 ± 3 g/L) 1 year after the operation were not statistically significant (P = .47) (Figure 3).

INCIDENCE OF DUMPING SYMPTOMS AND ENDOSCOPIC FINDINGS

Early dumping syndrome was found in 6 patients (40%) in the PPG group and in 21 patients (75%) in the CDG group (P = .03). The rate of patients with vasomotor symptoms in the CDG group (13 patients [46%]), however, was significantly higher (P = .02) than that in the PPG group (2 patients [13%]). The rate of patients with gastrointestinal symptoms in the CDG group (17 patients [61%]) tended to be higher than that in the PPG group (6 [40%]), although this was not significant (P = .06). On the other hand, late dumping syndrome was found in 7 patients (47%) in the PPG group and in 12 patients (43%) in the CDG group (P = .29). Ten patients in the PPG group and 9 patients in the CDG group were able to undergo an upper gastrointestinal tract endoscopy. In the PPG group, gastritis was shown in 2 patients and bile fluid regurgitation in 1 patient. In the CDG group, 4 patients had gastritis, 1 patient had both esophagitis and gastritis, and 1 patient had gastritis and bile fluid regurgitation. The rate of patients with endoscopic findings in the PPG group (3 patients [30%]) tended to be lower than that in the CDG group (6 patients [67%]), although the difference was not significant (P = .12).
The motility of the pyloric ring was retained, with the pyloric ring opening and closing well following the PPG procedure (Figure 4).

**COMMENT**

The dumping syndrome and alkaline reflux gastritis are the 2 major disorders among the postgastrectomy syndromes. The common reasons for occurrence for both are the rapid emptying of food into the intestine due to the loss of reservoir function after gastrectomy and the reflux of intestinal content due to the loss of pyloric function. A rapid emptying of large amounts of carbohydrate-rich liquid into the small intestine leads to the following physiological disorders: fluid shifts from the intravascular space into the bowel lumen produce gastrointestinal symptoms (early gastrointestinal dumping syndrome); the loss of intravascular volume stimulates the release of several enteric hormones, which causes early vasomotor symptoms; and hyperinsulinemia due to the high carbohydrate concentrations in the small intestine subsequently causes hypoglycemia (late dumping syndrome). As many as two thirds of patients have had early dumping symptoms, and 15% of patients have had symptoms of alkaline reflux gastritis after gastric surgical therapy. These symptoms that are associated with eating generally result in decreased food intake and a rapid weight loss. Furthermore, bile fluid regurgitation into the gastric remnant has been demonstrated to be one of the risk factors for the development of gastric remnant cancer.

Because recent reviews in Japan elucidated the excellent 5-year survival rates for early gastric cancer (92.9%-97.7%) following radical gastrectomy, efforts to minimize postoperative morbidity and mortality and to obtain a better postoperative quality of life without affecting these survival rates have stimulated considerable interest. Subsequently, several limited surgical procedures for early gastric cancer have been developed, including radical gastrectomy with modified D1 lymphadenectomy, endoscopic mucosal resection, and PPG. The PPG procedure was originally applied to patients with peptic ulcer to alleviate these disorders by preserving the pyloric function. In patients with benign disease, the incidence of dumping syndromes and reflux gastritis reportedly decreased more after PPG than after CDG. Consequently, PPG has also been developed as one of the limited treatment modalities for early gastric cancer.

Several investigations have been done of the postoperative functional evaluation of the gastric remnant following PPG for early gastric cancer. In these previously reported PPG procedures, the right gastric artery with the suprapyloric lymph nodes or pyloric branch of the vagus nerve was preserved. The aim of these procedures was the preservation of pyloric blood flow and motility. The preservation of the right gastric artery, however, meant an incomplete D1 lymphadenectomy because suprapyloric lymph nodes that were classified as N1 could not be dissected. Therefore, the indications of PPG are inevitably restricted. An experience at our institute and a recent review demonstrate that the rates of pN1 and pN2 lymph node metastases were 0.7% to 4.7% and 0% to 2.4%, respectively, in mucosal gastric cancer, and 11.4% to 18.9% and 2.3% to 8.2%, respectively, in submucosal gastric cancer. Therefore, the scope of lymphadenectomy should be a modified D1 for mucosal gastric cancer and D2 for sub-

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**Figure 2.** The mean serum total protein concentrations, before and 1 year after the operation, in the patients undergoing pylorus-preserving gastrectomy (PPG) and conventional distal gastrectomy (CDG). The difference between the 2 groups in the mean serum total protein concentration 1 year after the operation is not significant (P = .09). Bars indicate SD.

**Figure 3.** The mean serum albumin concentrations, before and 1 year after the operation, in the patients undergoing pylorus-preserving gastrectomy (PPG) and conventional distal gastrectomy (CDG). The difference between the 2 groups in the mean serum albumin concentrations 1 year after surgical therapy is not significant (P = .47). Bars indicate SD.

**Figure 4.** Upper gastrointestinal tract endoscopy reveals that the pyloric ring opened (left) and closed (right) well after the pylorus-preserving gastrectomy.
mucosal gastric cancer. Our PPG procedure, which involves the dissection of suprapylorick lymph nodes and of the pyloric branch of the vagus nerve, could achieve a modified D1 or a complete D2 lymphadenectomy.

We are unaware of any studies that have evaluated gastric function after PPG with dissection of the suprapylorick lymph nodes and the pyloric branch of the vagus nerve. To confirm the feasibility and safety of our PPG procedure, changes in nutritional state before and after surgical intervention, the incidence of early and late dumping syndromes, and postoperative endoscopic findings were compared between the PPG and the CDG groups. Although the postoperative serum levels of total protein and albumin were not statistically different between the 2 groups, the ratio of body weight increase was statistically higher in the PPG group than in the CDG group. With regard to dumping syndromes, the incidences of early dumping syndrome and vasmotor symptoms were significantly lower in the PPG group than in the CDG group. The incidences of gastrointestinal symptoms and the rate of adverse endoscopic findings in the PPG group tended to be lower than those in the CDG group. These results suggest that our PPG procedure could reduce the incidence of the dumping syndrome and reflux of intestinal content. Furthermore, upper gastrointestinal tract endoscopy elucidated the preservation of the pyloric sphincter function even if the pyloric branch of the vagus nerve was resected. The absence of anastomotic leakage in both treatment groups means that the dissection of the right gastric artery did not compromise the blood supply around the anastomosis. Our clinical results are supported by recent advances in knowledge about the blood supply and motility around the pylorus. The finding that more than 80% of the infrapylorick artery originates from the gastroduodenal artery suggests that the suprapylorick and infrapylorick lymph nodes could be dissected with safety. It was also shown that the stomach could retain good motility even though the pyloric branch of the vagus nerve was resected. Our findings relative to gastric function after PPG are consistent with those of previously reported studies of PPG and show the superiority of PPG over CDG. Furthermore, we have demonstrated that a complete D2 lymphadenectomy accompanying PPG does not negate these benefits in postoperative gastric function and can be safely performed if the infrapylorick artery is preserved.

CONCLUSIONS

Our study has shown the safety and feasibility of performing an extended lymphadenectomy in conjunction with PPG. This development suggests that PPG can be extended to a much broader segment of patients with gastric cancer than has been previously reported.

REFERENCES