



Early Postoperative Evaluation of Pylorus-Preserving Gastrectomy for Gastric Cancer

Masashi Kodama, M.D., Kenji Koyama, M.D., Teisao Chida, M.D., Akira Arakawa, M.D., Gennady Tur, M.D.

Department of Surgery, Akita University School of Medicine, 1-1-1, Hondo Akita 010, Japan

Abstract. Early postoperative evaluation was prospectively performed in 35 gastric cancer patients after pylorus-preserving gastrectomy (PPG) between 1989 and 1991, comparing the results with those of 29 patients who underwent conventional distal gastrectomy (CDG). Surgical stress, including the duration of operation (149.0 ± 4.3 minutes) and the total volume of bleeding at operation (97.0 ± 11.2 g), was significantly less in the PPG patients. Early postoperative complications were seen in 31% after PPG and in 35% after CDG. The most frequent complication in PPG patients was remnant gastric stasis (23%). Endoscopy showed redness or erosion (or both) of the gastric remnant in 17% after PPG and in 81% after CDG. Bile regurgitation was demonstrated in 11% after PPG and in 62% after CDG. In PPG patients, the pyloric ring opened and closed during the examination. Gastric pH was 4.2 ± 0.4 in PPG patients but was significantly lower in CDG patients. The resting gallbladder area, examined by ultrasonography, demonstrated no changes after PPG but was significantly enlarged after CDG (from 11.3 ± 1.2 cm² to 15.8 ± 1.5 cm² at 2 weeks). The percentage of the original resting gallbladder area at 20 minutes after injection of cerulein increased slightly in PPG patients but recovered thereafter, whereas in CDG patients it increased significantly (from $39.4 \pm 8.3\%$ to $66.7 \pm 9.1\%$ at 2 weeks). No gallstone formation was detected throughout the observation period after PPG, whereas after CDG it was detected in two patients at 1 year. These results indicated that PPG for gastric cancer has advantages over CDG in terms of surgical stress, the condition of the gastric remnant, and gallbladder function.

With pylorus-preserving gastrectomy (PPG) for benign gastric diseases, proposed by Maki et al. [1], such advantages as avoidance of the dumping syndrome [2] and protection of mucosal injury of the remnant stomach due to duodenal reflux [3, 4] are obtained owing to the preserved pyloric function. We have adopted this operation for patients with gastric cancer to obtain better postoperative quality of life because of the indications we reported in 1991 [5]. Different from the original procedure, our PPG requires subpyloric skeletonization and lymph node dissection. If we perform PPG for patients with gastric cancer instead of the conventional distal gastrectomy, such advantages as more ingestion of food, less damage of the remnant gastric mucosa, and lower occurrence of postgastrectomy cholecystolithiasis can be expected during the postoperative course. Because a pyloric cuff of 1.5 cm in length is retained with our operation, the hepatic and pyloric branches of the vagal nerve and the right gastric vessels with the suprapyloric lymph node are preserved.

A prospective study was performed to evaluate the postoperative status of gastric cancer patients after PPG, comparing these results with those after conventional distal gastrectomy. The factors evaluated were surgical stress, early postoperative condition and complications, endoscopic and pH studies of the gastric remnant, and gallbladder function.

Patients and Methods

The indications for PPG for early gastric cancer located in the middle third of the stomach were, as we reported elsewhere [5]: (1) any patient with tumors < 2.0 cm in maximum length; and (2) patients with a tumor of 2.0 to 4.0 cm if it is a mucosal cancer, if it is located at the greater curvature, or if it is an elevated-type (IIa) cancer. There were 64 patients who met above-mentioned conditions who were admitted to our department between 1989 and 1991. PPG was performed in 35 patients and conventional distal gastrectomy (CDG) in 29 patients—randomly with consent of the patients after adequate information was supplied.

During the PPG procedure a pyloric cuff of 1.5 cm in length was retained, and the hepatic and pyloric branches of the vagal nerve and right gastric vessels with the suprapyloric lymph node were preserved; dissection of the lesser and the greater curvature lymph node, subpyloric lymph node, and left gastric artery lymph node was performed. On the other hand, with CDG the group 1 and 2 lymph nodes were dissected, and reconstruction was undertaken by gastroduodenostomy.

Evaluation of the postoperative state of the patients after PPG took into account surgical stress, the early postoperative condition and complications, endoscopic and pH study of the gastric remnant, and gallbladder functions; these results were then compared with those obtained after CDG. The surgical stress and early postoperative condition evaluation included the blood loss at operation, the duration of the operation, the duration of fasting after operation, the dietary intake at discharge, and the duration of hospital stay. Endoscopic findings, including the presence or absence of mucosal redness or erosion and bile regurgitation, were available for 18 PPG patients and 16 CDG patients at 1 year after surgery. Gastric pH was measured by a gastric pH catheter

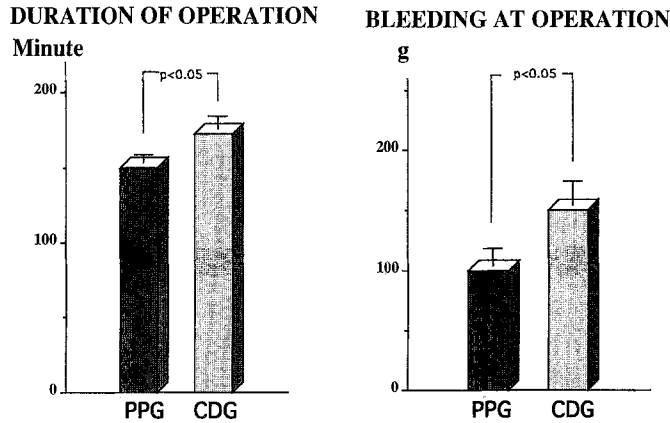


Fig. 1. Surgical stress including the duration and blood loss at operation is less for pylorus-preserving gastrectomy (PPG) than for conventional distal gastrectomy (CDG).

(Zinetics Medical, Salt Lake City, Utah, U.S.A.) in the left lateral position after thorough postural change before breakfast.

Gallbladder functions were prospectively studied using ultrasonography in 20 PPG patients and 11 CDG patients; scans were obtained before operation and at 2 weeks, 6 months, and 1 year after operation as follows: (1) gallbladder area; (2) gallbladder contractile function; and (3) frequency of sludge and gallstone formation. The gallbladder area was measured by a planimeter in the ultrasonographic apparatus. The gallbladder contractile function was determined by calculating the ratio of the gallbladder area at 20 minutes after intramuscular injection of 20 µg of cerulein to the original gallbladder area. The patients had consented to the test for gallbladder function, which was investigated for 20 minutes after injection of cerulein by ultrasonography. They were informed that gallbladder function, including resting gallbladder area and gallbladder contractile function, was closely related to the occurrence of postgastrectomy cholecystolithiasis.

Results were expressed as means ± SEM. The Student *t*-test was used for statistical analysis. Values of *p* < 0.05 were considered significant.

Results

Surgical Stress and Early Postoperative Conditions

The duration of the PPG operation was 149 ± 4.3 minutes, significantly shorter than the CDG procedure, as shown in Figure 1. The total volume of bleeding at operation for PPG was 97 ± 11.2 g, significantly less than that for CDG. With PPG, the duration of nothing per os after surgery was 3.3 ± 0.2 days, the diet intake at discharge was 50 ± 4%, and the duration of hospital stay was 18.2 ± 0.8 days, as shown in Figure 2. There was no difference between PPG and CDG for these parameters.

Early Postoperative Complications

The most frequent complication was remnant gastric stasis, as shown in Table 1. With PPG, six patients (17%) demonstrated mild stasis and two (6%) had severe stasis, whereas there were five patients (17%) and three patients (10%), respectively, for CDG.

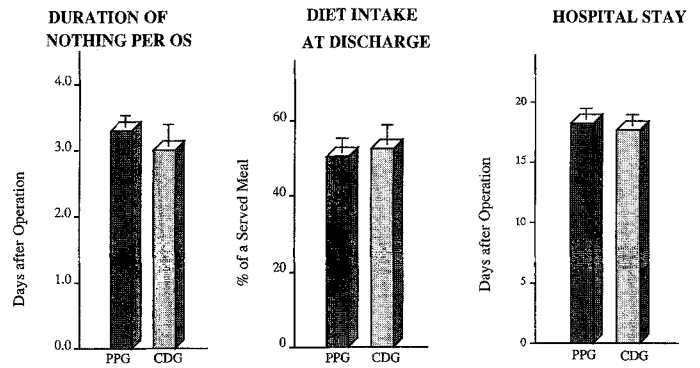


Fig. 2. Early postoperative conditions demonstrate no difference between pylorus-preserving gastrectomy (PPG) and conventional distal gastrectomy (CDG).

Table 1. Early postoperative complications.

Complication	PPG (n = 35)	CDG (n = 29)
Remnant gastric stasis		
Mild ^a	6 (17%)	5 (17%)
Severe ^b	2 (6%)	3 (10%)
Liver dysfunction	1	1
Pneumonia	1	0
Enterocolitis	0	1
Wound infection	1	0
<i>Total</i>	11 (31%)	10 (34%)

^aPatients with a mild sense of fullness after meals with slight dilatation of the gastric remnant.

^bPatients with a severe symptom required fasting and infusion therapy.

Table 2. Endoscopic findings in the gastric remnant 1 year after operation.

Procedure	Redness, erosion			Bile regurgitation
	Mild (no.)	Severe (no.)	Total (%)	
PPG (n = 18)	3	0	17	2 (11%)
CDG (n = 16)	7	6	81	10 (62%)

Postoperative hemorrhage and anastomotic leakage were not observed. Overall, early postoperative complications were seen in 11 patients (31%) after PPG and 10 patients (35%) after CDG; there was no significant difference between the two groups of patients.

Endoscopic Findings and pH of the Gastric Remnant

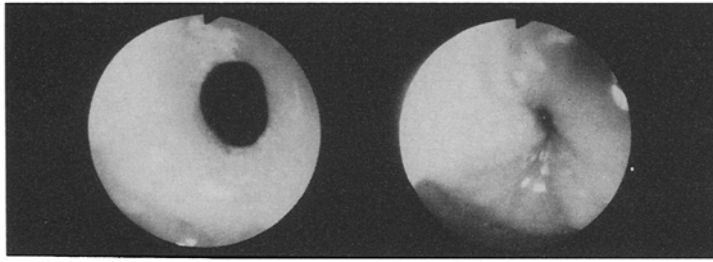
The endoscopic findings at 1 year after operation are shown in Table 2. After CDG, redness, erosion, or both of the gastric remnant were indicated in 13 patients (81%), and half of these cases were severe. After PPG, however, only three patients (17%) showed slight redness. Bile regurgitation was observed in 62% of patients after CDG but in only 11% after PPG. In PPG patients the pyloric ring was demonstrated to open and close during the examination. Figure 3 shows a well functioning

Preserved pylorus:

open

closed

Endoscopy



Barium meal study

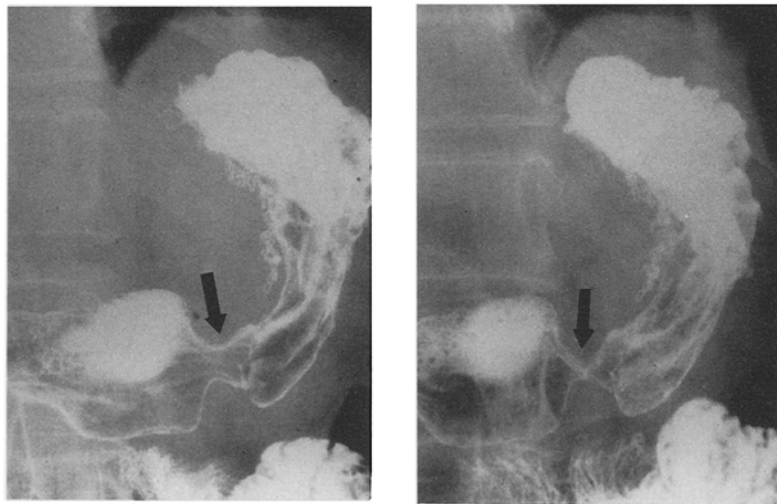


Fig. 3. Endoscopy and a barium meal study show that the pyloric ring opens and closes well after pylorus-preserving gastrectomy.

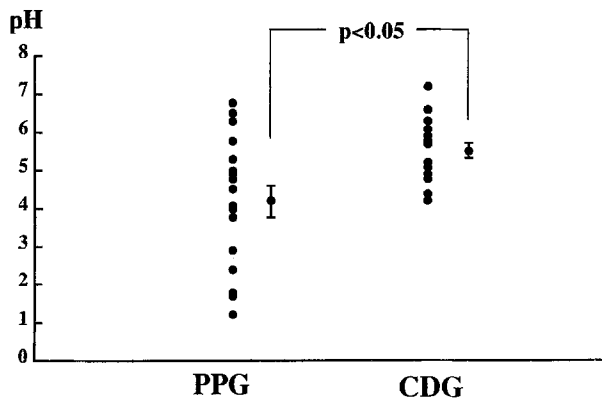


Fig. 4. Gastric pH study indicates a lower pH value for the pylorus-preserving gastrectomy (PPG) than for the conventional distal gastrectomy (CDG).

pyloric ring during endoscopy and a barium meal study. The gastric pH was 4.2 ± 0.4 in PPG patients, significantly lower than that in CDG patients, as shown in Figure 4. These results indicated that the condition of the gastric remnant after PPG was better than after CDG, owing to the prevention of bile regurgitation.

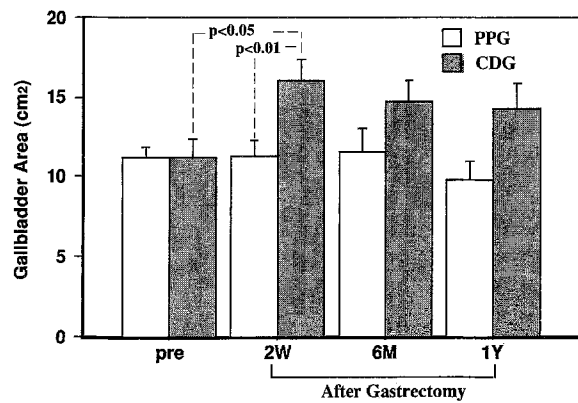


Fig. 5. Resting gallbladder area demonstrates no change after pylorus-preserving gastrectomy (PPG), whereas it is enlarged 2 weeks after conventional distal gastrectomy (CDG).

Gallbladder Function

Changes in resting gallbladder area are shown in Figure 5. After PPG there were no significant changes throughout the observation period. After CDG, however, the resting area was significantly enlarged after surgery (from $11.3 \pm 1.2 \text{ cm}^2$ to 15.8 ± 1.5

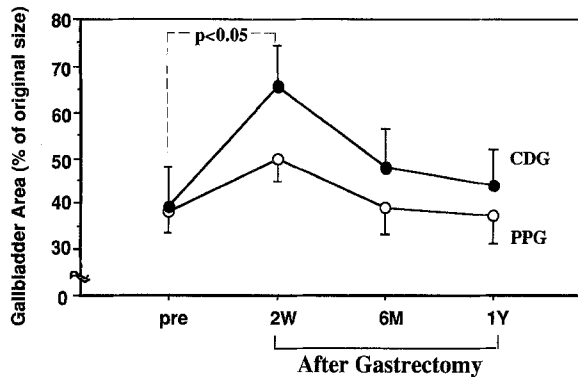


Fig. 6. Gallbladder contractile function is not particularly affected after pylorus-preserving gastrectomy (PPG), whereas it is suppressed 2 weeks after conventional distal gastrectomy (CDG).

cm² at 2 weeks), and it had not returned to preoperative levels at 1 year. The resting gallbladder area after CDG was also significantly enlarged at 2 weeks compared with that after PPG. Changes in gallbladder contractile function are shown in Figure 6. After PPG the percentage of the original resting gallbladder area after injection of cerulein increased (from 38.4 ± 4.8% at 20 minutes to 52.1 ± 6.4% at 2 weeks) but recovered thereafter. After CDG it showed similar changes, but it significantly increased (from 39.4 ± 8.3% to 66.7 ± 9.1% at 2 weeks). These results indicate that the gallbladder contractile function was suppressed by both PPG and CDG, but the extent was slight in PPG. The incidence of sludge and stone formation is shown in Table 3. After PPG no stone formation was detected throughout the observation period, and sludge formation was seen in four patients (20%) at 2 weeks, in two patients (10%) at 6 months, and in one patient (5%) at 1 year. After CDG, however, stone formation was detected in one patient (9%) at 6 months and in two patients (18%) at 1 year. Sludge formation was seen in three patients (27%) at 2 weeks, in four patients (36%) at 6 months, and in two patients (18%) at 1 year.

Discussion

We have adopted the PPG procedure for some patients with early gastric cancer under strict indications [5]. With this operative procedure we performed regional lymph node dissection (e.g., the lesser and greater curvature lymph nodes, subpyloric lymph nodes, and left gastric artery lymph nodes), but we were able to preserve the hepatic and pyloric branches of the vagal nerve and right gastric vessels uninjured. The results are different when using the CDG procedure.

The present study revealed that gastric pH was lower and the gastric mucosal injury was less in PPG patients. These results are the result of preserved pyloric function, as had been indicated by an experimental study. The latter had shown that the preserved pylorus functioned well after PPG, as the suprapyloric and subpyloric regions remained uninjured, including the vagal innervation and blood supply [6], and that a vagal cooling blockade abolished coordinated contractions between the pyloric ring and the duodenum, which prevented reflux of duodenal contents into the stomach [7]. In our present study, most of the patients had a well functioning pylorus, but remnant gastric stasis with treatment

Table 3. Incidence of sludge and gallstones.

Procedure	2 Weeks	6 Months	1 Year
PPG (n = 20)			
Sludge	4 (20%)	2 (10%)	1 (5%)
Gallstones	0	0	0
CDG (n = 11)			
Sludge	3 (27%)	4 (36%)	2 (18%)
Gallstones	0	1 (9%)	2 (18%)

was observed in two (6%) patients. We believe that it was caused by skeletonization of the subpyloric region with the subpyloric lymph node dissection.

It was recently reported that preservation of the supraduodenal artery and vagal innervation of the antrum was essential for preventing gastric stasis. During clinical studies with pyloric- and gastric-preserving pancreatic resection [8] it was found that the intestinal nerve plexus damage was more severe than the mucosal injury in ischemic and hypoxic states, and it took more time to recover [9]. Therefore, when we perform PPG with the pyloric branch of the vagal nerve uninjured it is inevitable to preserve right gastric vessels in order to avoid the dumping syndrome and prevent mucosal injury due to bile regurgitation.

Recent reports have pointed out that patients who undergo standard gastrectomy are at increased risk for the development of cholecystolithiasis, the incidence reported to be 16% to 37% [10, 11]. Such formations are thought to be associated with dilatation and deterioration of contractile function of the gallbladder, causative factors of which are probably removal of the hepatic branch of the vagal nerve [10–13], disordered gut hormone secretion due to gastrointestinal reconstruction [10], long-term total parenteral nutrition [14], and adhesion of the gallbladder to the surrounding organs. For those factors described above, denervation of the vagal nerve can play an important role in stone formation [15, 16]. Our recent investigation of the quality of life after gastrectomy for gastric cancer [17] revealed that stone formation was detected in 27% of the patients after total gastrectomy with truncal vagotomy at the level of the abdominal esophagus, which supports the importance of innervation of the vagal nerve. The present study disclosed that the resting gallbladder area was not affected and that gallbladder contractile function was less suppressed after PPG; moreover, no gallstone formation has been demonstrated so far. These results indicate that denervation of the hepatic branch of the vagal nerve plays an important role in the formation of gallstones after gastrectomy, and that PPG has the advantage of decreasing the incidence of postgastrectomy cholecystolithiasis.

It is valuable to know that a limited operation such as the PPG is superior to the standard operation with lymph node dissection in terms of postoperative quality of life. It is reasonable that PPG produced less surgical stress than CDG because the range of the resected stomach and lymph node dissection were limited during the PPG procedure. The present study disclosed that PPG had advantages over CDG in terms of surgical stress, the condition of the gastric remnant, and gallbladder function. We believe that PPG should be used in some early gastric cancer patients instead of CDG, with the anticipation of obtaining better postoperative results.

Résumé

Les différentes formes de tolérance de la gastrectomie avec conservation du pylore (GCP) ont été évaluées chez 35 patients opérés de cancer gastrique entre 1989 et 1991, et comparées aux résultats observés chez 29 patients après une gastrectomie distale conventionnelle (GDC). Le stress chirurgical, défini par la durée de l'intervention (149 ± 4.3 min.) et le volume total de saignement au cours de l'intervention (97 ± 11.2 g), étaient statistiquement moindres en cas de GCP qu'en une de GDC. Il y avait 31% de complications postopératoires après GCP et 35% après GDC. La complication la plus fréquente après GCP a été la stase du moignon gastrique, observée dans 23% des cas. L'endoscopie montrait chez 17% de ces patients opérés de GCP et chez 81% des patients après GDC, une rougeur et/ou des érosions du moignon gastrique. Un reflux bilieux a été constaté chez 11% des patients après GCP et chez 62% après GDC. Chez les patients ayant eu une GCP, on a pu mettre en évidence une ouverture et une fermeture de l'anneau pylorique pendant l'examen. Le pH gastrique était de 4.2 ± 0.4 dans la GCP, significativement plus bas qu'après la GDC. L'échographie a montré une augmentation de la surface vésiculaire après GDC, allant de 11.3 ± 2 cm² à 15.8 ± 5 cm², statistiquement plus importante qu'après GCP. Après la GCP, la surface a augmenté légèrement 20 minutes après l'injection de céruléine, alors qu'après GDC, elle a augmenté significativement de $39.4 \pm 8.3\%$ à $66.7 \pm 9.1\%$ (à deux semaines). Après GCP, on n'a pas observé de formation de lithiase pendant toute la période d'observation alors qu'après GDC, deux cas de lithiase ont été observés à un an. Ces résultats indiquent que la GCP pour cancer gastrique a des avantages certains par rapport à la GDC surtout en ce qui concerne le fonctionnement et l'état du moignon gastrique et la fonction vésiculaire.

Resumen

Se hizo una evaluación prospectiva en el período postoperatorio temprano luego de gastrectomía con preservación del píloro (PPG) en 35 pacientes con cáncer gástrico entre 1989 y 1991, comparándolos con 29 pacientes sometidos a gastrectomía distal convencional (CDG). El estrés quirúrgico, incluyendo la duración de la operación (149 ± 4.3 min) y el volumen total de hemorragia durante la operación (97 ± 11.2 g) fueron significativamente menores en la PPG. Complicaciones postoperatorias tempranas aparecieron en 31% de los casos con PPG y en 35% de los casos con CDG. La complicación más frecuente en la PPG fue la estasis del remanente gástrico en 23% de los casos. La endoscopia demostró enrojecimiento y/o erosión del remanente gástrico en 17% de los pacientes luego de PPG, contra 81% luego de CDG. Se demostró regurgitación biliar en 11% luego de PPG, y en 62% luego de CDG. En los pacientes con PPG, el anillo pilórico se vio abrir y cerrar en el curso del examen. El pH gástrico fue 4.2 ± 0.4 en PPG y significativamente más bajo que en los pacientes con CDG. La vesícula biliar en reposo estudiada mediante ultrasonografía señaló que no había cambios luego de PPG; sin

embargo, apareció significativamente agrandada de tamaño luego de CDG, de 11.3 ± 1.2 cm² a 15.8 ± 1.5 cm² (2 semanas). El porcentaje del área original de la vesícula en reposo a los 20 minutos luego de la inyección de ceruleína aumentó levemente en la PPG pero luego se recuperó, en tanto que en la CDG aumentó significativamente de $39.4 \pm 8.3\%$ a $66.7 \pm 9.1\%$ (2 semanas). Luego de la PPG no se detectó formación de cálculos biliares durante el período de observación, pero sí se detectó en dos pacientes al año luego de CDG. Estos resultados indican que la PPG para cáncer gástrico tiene ventajas en cuanto a estrés quirúrgico, condición del remanente gástrico y función de la vesícula biliar, sobre la CDG.

References

- Maki, T., Shiratori, T., Harafuku T., Sugawara, K.: Pylorus-preserving gastrectomy as an improved operation for gastric ulcer. *Surgery* 61:838, 1967
- Sekine, T., Sato, T., Maki, T., Shiratori, T.: Pylorus-preserving gastrectomy for gastric ulcer: one to nine year follow-up study. *Surgery* 77:92, 1975
- Sugiyama, Y., Sohma, H., Ozawa, M., et al.: Regurgitant bile acids and mucosal injury of the gastric remnant after partial gastrectomy. *Am. J. Surg.* 153:399, 1987
- Langhans, P., Hegar, R.A., Hohenstein, J., Schlake, W., Bunte, H.: Operation-sequel carcinoma of the stomach: experimental studies of surgical techniques with or without resection. *World J. Surg.* 5:595, 1981
- Kodama, M., Koyama, K.: Indication for pylorus preserving gastrectomy for early gastric cancer located in the middle third of the stomach. *World J. Surg.* 15:628, 1991
- Ohnishi, A.: Electrophysiological studies on the motility of the preserved pylorus after pylorus preserving gastrectomy in dog. *J. Kyoto Prefectural Univ. Med.* 87:197, 1978
- Suzuki, E.: Interdigestive contractile characteristics of canine pylorus and gastroduodenal regions. *J. Smooth Muscle Res.* 27:139, 1991
- Braasch, J., Rossi, R., Watkins, E., Jr., Desiel, D., Winter, P.: Pylorus and gastric preserving pancreatic resection: experience with 87 patients. *Ann. Surg.* 204:411, 1986
- Chen, D., Onda, M., Moriyama, Y., Nakajima, Y.: Immunohistochemical studies on damage of intestinal nerve plexuses in ischemic state. *Jpn. J. Gastroenterol. Surg.* 25:2732, 1992
- Horwitz, A., Kirson, S.M.: Cholecystitis and cholelithiasis as a sequel to gastric surgery: a clinical impression. *Am. J. Surg.* 109:760, 1965
- Tompkins, R.K., Kraft, A.R., Zimmerman, E., Lichtenstein, J.E., Zollinger, R.M.: Clinical and biochemical evidence of increased gallstone formation after complete vagotomy. *Surgery* 71:196, 1972
- Cox, H.T., Doherty, J.F., Kerr, D.F.: Changes in the gallbladder after elective gastric surgery. *Lancet* 1:764, 1958
- Fletcher, D.M., Clark, C.G.: Gallstones and gastric surgery: a review. *Br. J. Surg.* 55:895, 1968
- Pitt, H.A., King, W., III, Mann, L.L.: Increased risk of cholecystolithiasis with prolonged parenteral nutrition. *Am. J. Surg.* 145:106, 1983
- Johnson, F.E., Boyden, E.A.: The effect of double vagotomy on the motor activity of the human gallbladder. *Surgery* 32:591, 1952
- Inoue, K., Fuchigami, A., Higashide, S., et al.: Gallbladder sludge and stone formation in relation to contractile function after gastrectomy: a prospective study. *Ann. Surg.* 215:19, 1992
- Kodama, M., Koyama, H., Sone, S., Sakusabe, M., Narisawa, T., Koyama, K.: Quality of life after resection of stomach by questionnaire. *J. Jpn. Soc. Clin. Surg.* 51:466, 1990