

Roux-en-Y Reconstruction After Pancreaticoduodenectomy

Stephen R. Grobmyer, MD; Scott T. Hollenbeck, MD; David P. Jaques, MD; William R. Jarnagin, MD; Ronald DeMatteo, MD; Daniel G. Coit, MD; Leslie H. Blumgart, MD; Murray F. Brennan, MD; Yuman Fong, MD

Hypothesis: Roux-en-Y reconstruction (RYR) is associated with a reduction in morbidity and mortality associated with pancreatic anastomotic failure after pancreaticoduodenectomy compared with conventional loop reconstruction (CLR).

Design: Retrospective study of patients from 1991 to 2006.

Setting: Tertiary care center.

Patients: Records of patients undergoing CLR (n=588) and patients undergoing RYR (n=112) between February 1, 1991, and June 30, 2006, for pancreatic ductal adenocarcinoma at a single institution were retrospectively reviewed and compared.

Main Outcome Measures: Perioperative outcome and mortality were compared for patients who underwent RYR compared with those who underwent CLR.

Results: Overall, both groups required a similar rate of postoperative interventional radiology procedures (CLR, 6.8%; RYR, 9.8%; $P=.24$) and subsequent operations (CLR, 6.9%; RYR, 9.1%; $P=.62$). No significant difference was found in the rate of overall postoperative mortality (CLR, 2.6%; RYR, 0.9%; $P=.49$). The overall rate of pancreatic anastomotic failure was 7.2%, and pancreatic anastomotic failure was associated with a 6% mortality rate. Among patients who developed pancreatic anastomotic failure, no significant difference was seen between CLR (n=32) and RYR (n=16) in length of hospital stay (18 vs 19 days; $P=.98$) or postoperative mortality (3 patients [9.4%] vs none [0%]; $P=.54$).

Conclusion: We found that RYR is not associated with a reduction in morbidity after pancreaticoduodenectomy for pancreatic adenocarcinoma compared with CLR, even among patients who develop pancreatic anastomotic failure.

Arch Surg. 2008;143(12):1184-1188

PANCREATICODUODENECTOMY is associated with a high rate of postoperative complications and morbidity.¹⁻⁵ Pancreatic anastomotic failure remains among the most common and potentially lethal postoperative complications of pancreaticoduodenectomy.^{5,6} Patients with pancreatic anastomotic failure may require subsequent operation or postoperative interventional radiology drainage procedures.^{4,7} Mortality is reported in association with postoperative pancreatic failure, although the associated mortality rate has decreased in recent years.^{5,6}

There has been long-standing interest in the development of techniques to reduce the rate of pancreatic anastomotic leakage^{1,4,8-11} and its associated morbidity.^{12,13} Use of a Roux-en-Y loop for reconstruction (RYR) of pancreatic drainage is a technique that has been suggested to reduce pancreatic anastomotic leak-related mor-

bidity and mortality in patients undergoing pancreaticoduodenectomy.¹⁴⁻²⁴ It has been suggested that isolation of the pancreatic anastomosis from the biliary and gastric anastomoses prevents activation of the secreted inactive precursor pancreatic enzymes by low gastric pH or enterokinase.^{14,15,18,19} This, it has been suggested, results in lower morbidity and mortality rates in the setting of pancreatic anastomotic failure¹⁹ because inactive pancreatic enzyme precursors are not associated with "serious complications."¹⁵ Kingsnorth¹⁸ has referred to pancreatic anastomotic failure after RYR as "relatively benign."

In this report, we describe a large single-institutional experience with the use of a Roux-en-Y limb for pancreatic reconstruction after pancreaticoduodenectomy for pancreatic ductal adenocarcinoma. The results are presented in the context of a series of patients who underwent a stan-

Author Affiliations:
Department of Surgery, Memorial Sloan-Kettering Cancer Center, New York, New York. Dr Grobmyer is now with the Division of Surgical Oncology, Department of Surgery, University of Florida, Gainesville.

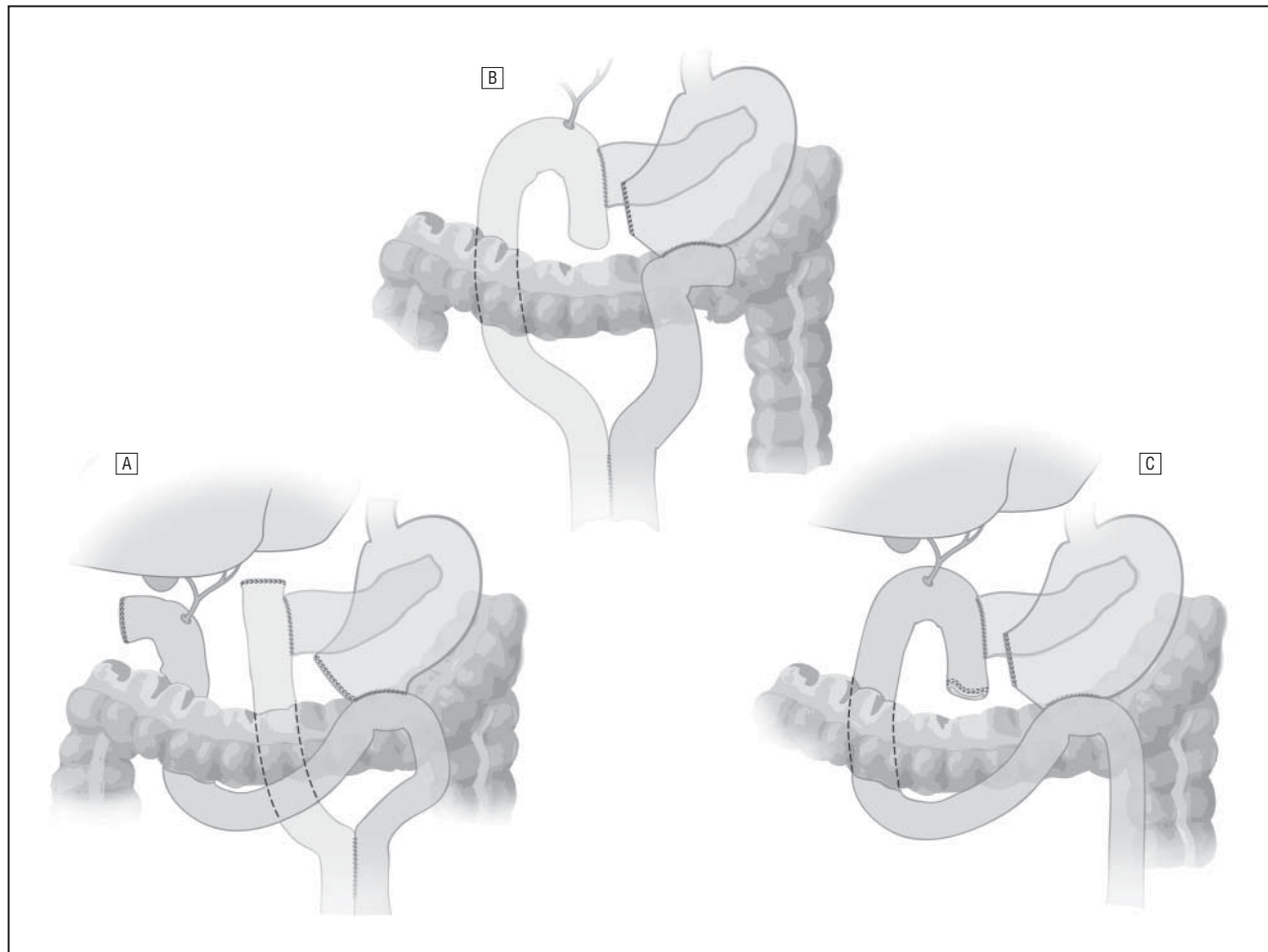


Figure. Types of reconstruction after pancreaticoduodenectomy analyzed in this report. A, Isolated Roux limb to the pancreas and Roux limb to the bile duct. B, Single Roux limb to both the pancreas and bile duct. C, Conventional loop reconstruction.

standard reconstruction after pancreaticoduodenectomy during the same period. The goal of this study was to determine whether RYR is associated with better overall outcomes and with better outcomes among the subset of patients who have pancreatic anastomotic failure after pancreaticoduodenectomy.

METHODS

Patients undergoing pancreaticoduodenectomy for pancreatic ductal adenocarcinoma between February 1, 1991, and June 30, 2006, were identified using the Memorial Sloan-Kettering Cancer Center Department of Surgery prospective pancreatic cancer database. Medical records were reviewed and information in the database confirmed by two of us (S.R.G. and S.T.H.). Complications were recorded and collected after medical record review by two of us (S.R.G. and S.T.H.). Reconstruction after pancreaticoduodenectomy was classified as either RYR (Figure, A and B) or conventional loop reconstruction (CLR) (Figure, C). Patients who underwent a pancreaticogastrostomy or other reconstructive procedures after pancreaticoduodenectomy were excluded from the analysis.

SURGICAL CONDUCT

The operations in this series were performed by 16 different surgical oncologists. The number of cases per surgeon ranged

from 1 to 216. The choice of reconstructive technique (RYR or CLR) was based on the decision of the operating surgeon. No data on factors leading to the decision to perform RYR or CLR were available in this retrospective study. The technique of pancreaticojejunal anastomosis was not standardized, and the choice of anastomosis was based on the decision of the operating surgeon. The use of pylorus-preserving procedures was not standardized. Anastomotic stenting of the pancreatic duct was not routinely used. Some patients in the series were participants in a randomized prospective trial of postoperative closed suction drainage.⁴ In all other cases, drains were placed at the discretion of the attending surgeon. Octreotide acetate was not routinely used in the perioperative period.

DATA COLLECTED

Data on operative time (incision to skin closure, including diagnostic laparoscopy), estimated blood loss, length of stay, development of a pancreatic anastomotic failure, development of delayed gastric emptying, and requirement for a postoperative interventional radiology procedure were collected for each patient. Complete data on postoperative complications and length of stay were not available for all patients. For each analysis, patients on whom no data were available were excluded. For the purposes of this report, pancreatic anastomotic failure was defined as more than 50 mL of amylase-rich (>3 times the serum amylase activity) drainage on or after postoperative day 5 from a drain placed at the time of the operation or during the

Table. Postoperative Morbidity and Mortality After Pancreaticoduodenectomy for Pancreatic Adenocarcinoma (1991-2006)^a

	Conventional Loop Reconstruction (n=588)	Roux-en-Y Reconstruction (n=112)	P Value
Delayed gastric emptying, %	10.3 (n=562)	10.1 (n=108)	.99
Pancreatic anastomotic failure, %	5.7 (n=562)	14.8 (n=108)	.002
Interventional radiology procedures, %	6.8 (n=577)	9.8 (n=112)	.24
Additional operations, %	6.9 (n=578)	9.1 (n=110)	.42
Length of hospital stay, median (range), d	10 (5-72) (n=565)	11 (5-52) (n=111)	.003
Length of hospital stay among those with pancreatic anastomotic failure, median (range), d	18 (10-66) (n=29)	19 (9-52) (n=16)	.98
Mortality, %	2.6 (n=580)	0.9 (n=111)	.54
Mortality among those with pancreatic anastomotic failure, %	9.4 (n=32)	0 (n=16)	.54

^aSample sizes (n) are numbers of patients for whom data were available.

postoperative period by interventional radiology or anastomotic leakage requiring subsequent operation. Delayed gastric emptying was defined as the requirement for replacement of a nasogastric tube on or after postoperative day 10 in the absence of an intra-abdominal collection or evidence of a small-bowel obstruction.

STATISTICAL ANALYSIS

Statistical analysis was performed using the Fisher exact test, χ^2 test, Mann-Whitney test, or Kruskal-Wallis test as appropriate (StatView Software, Loma Linda, California). Values reported are median (range). Events were considered statistically significant if $P < .05$. The study was approved by the Memorial Sloan-Kettering Cancer Center institutional review board.

RESULTS

DEMOGRAPHIC AND OPERATIVE PROCEDURES

Seven hundred patients who underwent a pancreaticoduodenectomy for pancreatic ductal adenocarcinoma were identified for analysis. One hundred twelve patients underwent RYR after pancreaticoduodenectomy. Of those who underwent RYR, 12 had an isolated Roux limb to the pancreas (Figure, A) and 100 had a Roux limb to the pancreas and bile duct (Figure, B). Five hundred eighty-eight underwent CLR (Figure, C).

The median age of patients in the series was 69 years (range, 36-90 years). No difference was found in the median age of patients in the 2 groups (RYR, 68 years [range, 36-83 years] vs CLR, 70 years [range, 38-90 years]; $P = .32$). A significant difference was found in the sex distribution of patients in the 2 groups (RYR, 62.5% female vs CLR, 51.1% female; $P = .03$).

No difference was seen in the rate of use of RYR during the period studied (1991-1995, 14.0%; 1996-2000,

13.7%; and 2001-2006, 18.7%; $P = .20$). Nine of 16 surgeons used RYR at least once. The rate of use of RYR among the surgeons ranged from 0% to 90%.

OPERATIVE RESULTS

The median operative time for all patients in this series was 5.2 hours (range, 1.8-11.7 hours). Median operating time varied significantly by surgeon ($P = .004$). Median operative time was significantly longer in the RYR group (5.8 hours [range, 2.6-10.3 hours]) compared with the CLR group (5.1 hours [range, 1.8-11.7 hours]) ($P = .001$). No significant difference was found in operative blood loss comparing each of the reconstruction techniques (RYR, 700 mL [range, 150-3500 mL]; and CLR, 700 mL [range, 200-5500 mL]; $P = .55$). Closed suction surgical drains were more commonly placed after RYR (80.4%) compared with CLR (60.0%) ($P < .001$).

POSTOPERATIVE RESULTS

No difference was found in the rate of interventional radiology drainage procedures required (RYR, 9.8% vs CLR, 6.8%; $P = .24$) or the rate of subsequent operation required (RYR, 9.1% vs CLR, 6.9%; $P = .62$). The median length of hospital stay among patients who survived the perioperative period was significantly shorter in the patients undergoing CLR (10 days [range, 5-72 days]) compared with those undergoing RYR (11 days [range, 5-52 days]) ($P = .003$). The overall rate of postoperative pancreatic anastomotic failure was 7.2%. No significant difference was observed in the rates of pancreatic anastomotic failure comparing surgeons in this study ($P = .26$). Pancreatic anastomotic failure was significantly more common in the patients undergoing RYR (14.8%) compared with those undergoing CLR (5.7%) ($P = .002$). The length of hospital stay was similar among patients who developed a pancreatic fistula (CLR, 18 days [range, 10-66 days] vs RYR, 19 days [range, 9-52 days]; $P = .98$). No difference was found in the rate of delayed gastric emptying in the 2 groups (CLR, 10.3% vs RYR, 10.1%; $P = .99$).

The overall postoperative mortality rate in the present series was 2.3%. No statistically significant difference was seen in the rate of postoperative mortality comparing the 2 groups (CLR, 2.6% vs RYR, 0.9%; $P = .54$). The causes of postoperative mortality of patients in this series were as follows: cardiac arrest (n=6 [38%]), sepsis or multiple organ dysfunction (n=4 [25%]), pancreatic fistula (n=3 [19%]), hemorrhage or disseminated intravascular coagulation (n=12 [22%]), and portal vein thrombosis (n=1 [6%]). No statistically significant difference was found in the percentage of pancreatic leaks associated with mortality in the 2 groups (CLR, 9.4% [3 of 32] vs RYR, 0% [0 of 16]; $P = .54$). The comparison between postoperative morbidity and mortality in the 2 groups is summarized in the **Table**.

COMMENT

Pancreatic anastomotic failure has been and remains a significant source of morbidity for patients undergoing pancreaticoduodenectomy.^{6,25} As a result, numerous strat-

gies have been investigated in an effort to reduce the rate of pancreatic anastomotic leakage. The technique of pancreaticojejunal anastomosis,⁸ use of pancreaticogastrostomy,⁹ occlusion of the pancreatic duct,¹⁰ stenting of the pancreatic duct,²⁶ use of postoperative octreotide acetate,¹ avoidance of closed suction surgical drains,⁴ and maintenance of good blood supply to the pancreatic remnant¹¹ have been concepts previously studied in an effort to reduce the rate and severity of pancreatic anastomotic leaks. Use of RYR for pancreatic drainage after pancreaticoduodenectomy has been suggested to reduce the morbidity associated with pancreatic anastomotic failure.^{14,15,18,19}

Use of RYR after pancreaticoduodenectomy was popularized by Machado et al.¹⁴ To our knowledge, no prospective randomized studies have been performed on the value of RYR of the pancreas after pancreaticoduodenectomy. Several case series have reported a reduction in the rate of pancreatic anastomotic leakage and mortality associated with pancreatic anastomotic leakage compared with historical controls.^{14-19,21-24,27} In these series the RYR of the limb was used for reconstruction of pancreatic drainage^{14,15,17-19,21-23,27} or both pancreatic and biliary drainage.^{15,16,24} Most of these series suffer from small sample size^{14,16,17,19,24,27} and lack appropriate controls, limiting the value of their conclusions. One other series¹⁵ has similarly compared outcomes among patients treated at a single institution. In that series, a difference was not found in pancreatic anastomotic leakage rate or leak-associated mortality rate comparing RYR and CLR techniques.

The present series does not support the concept that RYR is associated with less postoperative morbidity than CLR after pancreaticoduodenectomy even in the setting of pancreatic anastomotic failure. It is noteworthy that there was no mortality among RYR patients with pancreatic anastomotic failure; however, this finding was not statistically different from the mortality among CLR patients with pancreatic anastomotic failure (Table). The length of hospital stay was not statistically different among those with pancreatic anastomotic failure comparing patients undergoing CLR with those undergoing RYR.

The overall rate of pancreatic anastomotic failure (7.2%) in the present series is in accordance with other modern series.^{5,6} In the present series, patients who underwent RYR had a higher rate of pancreatic anastomotic leakage than those undergoing CLR. This finding likely represents a selection bias toward selection of RYR for those at high risk for pancreatic anastomotic leakage (eg, small pancreatic duct and soft texture of the pancreas). Accurate information on pancreatic texture and duct size could not be collected in this retrospective series. The patients undergoing RYR had longer operative times, which may be related to differences in surgeon operative times because the use of RYR varied greatly among surgeons. No overall significant difference was found in the rate of postoperative mortality comparing the 2 groups (CLR vs RYR). The incidence of mortality related to pancreatic fistula in the entire series was low (0.4%), and the mortality associated with pancreatic anastomotic failure was 6%.

The present study has several limitations. It was a retrospective study and not a randomized trial. Pancreatic texture and pancreatic duct size, 2 of the factors known to be most commonly associated with an increased rate of pancreatic anastomotic leakage, could not be analyzed in this series. A meaningful comparison between use of the Roux limb for pancreatic reconstruction vs pancreatic and biliary reconstruction is not possible in the present series given the small sample size in the former group. Finally, this series contains patients with pancreatic ductal adenocarcinoma, and the findings may not be applicable to other histologic types of tumors.

It remains possible that use of a Roux limb improves long-term postoperative quality of life in patients undergoing pancreaticoduodenectomy by reducing the incidence of postoperative bile reflux and gastritis.^{16,27} This issue has not been addressed in the present study. Such a question could only be evaluated effectively in a prospective fashion.

In conclusion, we find that use of pancreaticobiliary RYR after pancreaticoduodenectomy is not associated with significantly improved outcomes, even among patients who develop pancreatic anastomotic failure. The widespread use of RYR in preference to CLR after pancreaticoduodenectomy is not supported.

Accepted for Publication: September 17, 2007.

Correspondence: Yuman Fong, MD, Department of Surgery, Memorial Sloan-Kettering Cancer Center, 1275 York Ave, New York, NY 10065 (fongy@mskcc.org).

Author Contributions: *Study concept and design:* Grobmyer, Brennan, and Fong. *Acquisition of data:* Grobmyer, Hollenbeck, Jarnagin, Blumgart, and Brennan. *Analysis and interpretation of data:* Grobmyer, Jaques, DeMatteo, Coit, Blumgart, Brennan, and Fong. *Drafting of the manuscript:* Grobmyer, Hollenbeck, Jaques, Brennan, and Fong. *Critical revision of the manuscript for important intellectual content:* Grobmyer, Jarnagin, DeMatteo, Coit, Blumgart, Brennan, and Fong. *Statistical analysis:* Grobmyer. *Obtained funding:* Brennan and Fong. *Administrative, technical, and material support:* Grobmyer, Hollenbeck, Jarnagin, Coit, Blumgart, Brennan, and Fong. *Study supervision:* Blumgart, Brennan, and Fong.

Financial Disclosure: None reported.

Funding/Support: This study was supported in part by grants RO1 CA 75416 and RO1 CA/DK80982 (Dr Fong) from the National Institutes of Health, grant MBC-99366 (Dr Fong) from the American Cancer Society, and a Mr William H. Goodwin and Mrs Alice Goodwin and the Commonwealth Foundation for Cancer Research grant from The Experimental Therapeutics Center of Memorial Sloan-Kettering Cancer Center (Dr Fong).

REFERENCES

1. Lowy AM, Lee JE, Pisters PW, et al. Prospective, randomized trial of octreotide to prevent pancreatic fistula after pancreaticoduodenectomy for malignant disease. *Ann Surg.* 1997;226(5):632-641.
2. Yeo CJ, Cameron JL, Sohn TA, et al. Six hundred fifty consecutive pancreaticoduodenectomies in the 1990s: pathology, complications, and outcomes. *Ann Surg.* 1997;226(3):248-257.
3. Balcom JH, Rattner DW, Warshaw AL, Chang Y, Fernandez-del Castillo C. Ten-year experience with 733 pancreatic resections: changing indications, older patients, and decreasing length of hospitalization. *Arch Surg.* 2001;136(4):391-398.

4. Conlon KC, Labow D, Leung D, et al. Prospective randomized clinical trial of the value of intraperitoneal drainage after pancreatic resection. *Ann Surg.* 2001; 234(4):487-493.
5. Grobmyer SR, Pieracci FM, Allen PJ, Brennan MF, Jaques DP. Defining morbidity after pancreaticoduodenectomy: use of a prospective complication grading system. *J Am Coll Surg.* 2007;204(3):356-364.
6. Grobmyer SR, Rivadeneira DE, Goodman CA, Mackrell P, Lieberman MD, Daly JM. Pancreatic anastomotic failure after pancreaticoduodenectomy. *Am J Surg.* 2000;180(2):117-120.
7. Sohn TA, Yeo CJ, Cameron JL, et al. Pancreaticoduodenectomy: role of interventional radiologists in managing patients and complications. *J Gastrointest Surg.* 2003;7(2):209-219.
8. Marcus SG, Cohen H, Ranson JH. Optimal management of the pancreatic remnant after pancreaticoduodenectomy. *Ann Surg.* 1995;221(6):635-645.
9. Yeo CJ, Cameron JL, Maher MM, et al. A prospective randomized trial of pancreaticogastrostomy versus pancreaticojejunostomy after pancreaticoduodenectomy. *Ann Surg.* 1995;222(4):580-588.
10. Tran K, Van Eijck C, Di Carlo V, et al. Occlusion of the pancreatic duct versus pancreaticojejunostomy: a prospective randomized trial. *Ann Surg.* 2002;236(4):422-428.
11. Strasberg SM, Drebin JA, Mokadam NA, et al. Prospective trial of a blood supply-based technique of pancreaticojejunostomy: effect on anastomotic failure in the Whipple procedure. *J Am Coll Surg.* 2002;194(6):746-758.
12. Sikora SS, Posner MC. Management of the pancreatic stump following pancreaticoduodenectomy. *Br J Surg.* 1995;82(12):1590-1597.
13. Spanknebel K, Conlon KC. Advances in the surgical management of pancreatic cancer. *Cancer J.* 2001;7(4):312-323.
14. Machado MC, da Cunha JE, Bacchella T, Bove P. A modified technique for the reconstruction of the alimentary tract after pancreatoduodenectomy. *Surg Gynecol Obstet.* 1976;143(2):271-272.
15. Funovics JM, Zöch G, Wenzl E, Schulz F. Progress in reconstruction after resection of the head of the pancreas. *Surg Gynecol Obstet.* 1987;164(6):545-548.
16. Lygidakis NJ, Brummelkamp WH. A new approach for the reconstruction of continuity of the alimentary tract after pancreaticoduodenectomy. *Surg Gynecol Obstet.* 1985;160(5):453-458.
17. Kingsnorth AN. Duct to mucosa isolated Roux loop pancreaticojejunostomy as an improved anastomosis after resection of the pancreas. *Surg Gynecol Obstet.* 1989;169(5):451-453.
18. Kingsnorth AN. Safety and function of isolated Roux loop pancreaticojejunostomy after Whipple's pancreaticoduodenectomy. *Ann R Coll Surg Engl.* 1994; 76(3):175-179.
19. Albertson DA. Pancreaticoduodenectomy with reconstruction by Roux-en-Y pancreaticojejunostomy: no operative mortality in a series of 25 cases. *South Med J.* 1994;87(2):197-201.
20. Yeh TS, Jan YY, Chen MF. Roux loop obstruction after pancreaticoduodenectomy. *Br J Surg.* 1997;84(3):323-324.
21. Meyer C, Rohr S, De Manzini N, Thiry CL, Firtion O. Pancreatico-jejunal anastomosis with invagination on isolated loop after cephalic pancreatoduodenectomy [in Italian]. *Ann Ital Chir.* 1997;68(5):613-615.
22. Papadimitriou JD, Fotopoulos AC, Smyrniotis B, Prahalias AA, Kostopanagiotou G, Papadimitriou LJ. Subtotal pancreatoduodenectomy: use of a defunctionalized loop for pancreatic stump drainage. *Arch Surg.* 1999;134(2):135-139.
23. Khan AW, Agarwal AK, Davidson BR. Isolated Roux Loop duct-to-mucosa pancreaticojejunostomy avoids pancreatic leaks in pancreaticoduodenectomy. *Dig Surg.* 2002;19(3):199-204.
24. Ma YG, Li XS, Chen H, Wu MC. Pancreaticoduodenectomy with Roux-Y anastomosis in reconstructing the digestive tract: report of 26 patients. *Hepatobiliary Pancreat Dis Int.* 2002;1(4):611-613.
25. Trede M, Schwall G. The complications of pancreatotomy. *Ann Surg.* 1988;207(1):39-47.
26. Roder JD, Stein HJ, Böttcher KA, Busch R, Heidecke CD, Siewert JR. Stented versus nonstented pancreaticojejunostomy after pancreatoduodenectomy: a prospective study. *Ann Surg.* 1999;229(1):41-48.
27. Kingsnorth AN, Berg JD, Gray MR. A novel reconstructive technique for pylorus-preserving pancreaticoduodenectomy: avoidance of early postoperative gastric stasis. *Ann R Coll Surg Engl.* 1993;75(1):38-42.