Original article

Impact of bacterial contamination of the abdominal cavity during pancreaticoduodenectomy on surgical-site infection

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Background: **Several risk factors for complications after pancreaticoduodenectomy have been reported. However, the impact of intraoperative bacterial contamination on surgical outcome after pancreaticoduodenectomy has not been examined in depth.**

Methods: **This retrospective study included patients who underwent pancreaticoduodenectomy and peritoneal lavage using 7000 ml saline between July 2012 and May 2014. The lavage fluid was subjected to bacterial culture examination. The influence of a positive bacterial culture on surgical-site infection (SSI) and postoperative course was evaluated. Risk factors for positive bacterial cultures were also evaluated.**

Results: **Forty-six (21·1 per cent) of 218 enrolled patients had a positive bacterial culture of the lavage fluid. Incisional SSI developed in 26 (57 per cent) of these 46 patients and in 13 (7·6 per cent) of 172 patients with a negative lavage culture ($P < 0·001$). Organ/space SSI developed in 32 patients with a positive lavage culture (70 per cent) and in 43 of those with a negative culture (25·0 per cent) ($P < 0·001$). Grade B/C pancreatic fistula was observed in 22 (48 per cent) and 48 (27·9 per cent) respectively of patients with positive and negative lavage cultures ($P = 0·010$). Postoperative hospital stay was longer in patients with a positive lavage culture (28 days *versus* 21 days in patients with a negative culture; $P = 0·028$). Multivariable analysis revealed that internal biliary drainage, combined colectomy and a longer duration of surgery were significant risk factors for positive bacterial culture of the lavage fluid.**

Conclusion: **Intraoperative bacterial contamination has an adverse impact on the development of SSI and grade B/C pancreatic fistula following pancreaticoduodenectomy.**

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Introduction

The past decade has seen advances in surgical techniques and perioperative management that have made pancreaticoduodenectomy a safe procedure at high-volume centres. Postoperative mortality rates after pancreaticoduodenectomy have decreased to less than 5 per cent, but morbidity remains high, with rates of 35–88 per cent[1–8]. The development of pancreatic fistula and surgical-site infection (SSI) are among the more serious complications. Several factors that increase the risk of SSI have been described[9], such as obesity, a small main pancreatic duct, a longer duration of surgery and development of a pancreatic fistula. However, these factors are related only indirectly to SSI, and a likely explanation for the development of SSI is intraoperative bacterial contamination of the abdominal cavity.

To reduce morbidity related to intra-abdominal infections, surgeons should aim to isolate and control potential sources of contamination. Peritoneal lavage, as the final step of surgery, has been used to remove bacterial contamination and other substances that may promote bacterial proliferation, such as blood and proinflammatory cytokines. Most studies evaluating the efficacy of intraoperative peritoneal lavage have been conducted in patients with peritonitis[10] or under experimental conditions[11]. A few studies[12,13] have reported on patients undergoing elective colorectal resection, but none has been conducted in patients having pancreatic surgery. The present study collected data on bacterial cultures of lavage fluid after pancreaticoduodenectomy. The incidence of positive bacterial culture of lavage fluid and the impact of bacterial contamination on the postoperative course were investigated.

Risk factors for positive bacterial culture of the peritoneal lavage fluid were identified.

Methods

All patients who had pancreaticoduodenectomy between July 2012 and May 2014 at the authors' institution were included in this retrospective study. Preoperative biliary drainage was performed in patients with obstructive jaundice: external drainage as percutaneous transhepatic biliary drainage (PTBD) or endoscopic nasogastric biliary drainage (ENBD), or internal drainage as endoscopic retrograde biliary drainage. The pancreatic texture (soft or hard) was determined according to the intraoperative surgeon's subjective judgement by palpation.

The presence of an SSI was determined according to the Centers for Disease Control and Prevention's national nosocomial infections surveillance system, including incisional and organ/space SSI[14,15]. Pancreatic fistulas were classified into three categories (grade A, B or C) according to International Study Group on Pancreatic Fistula criteria[16]. Delayed gastric emptying was defined by International Study Group of Pancreatic Surgery clinical criteria[17]. Postoperative complications were described according to the Dindo–Clavien classification[18].

Perioperative bacterial culture and management

During surgery, bile juice was sampled for bacterial culture when the bile duct was transected. At the end of the operation, peritoneal lavage was performed using a total of 7000 ml normal saline (7 washings of 1000 ml). Clean suction apparatus was used, and surgeons exchanged their gloves before abdominal lavage. The fluid from the final lavage was collected for bacterial culture.

Prophylactic antibiotics were administered routinely in the perioperative period. In patients with a positive bile culture from biliary drainage, the choice of antibiotic was based on bacterial susceptibility. In patients with a negative bile culture, or with no bile culture owing to lack of biliary drainage or internal biliary drainage, a first-generation cephalosporin (cefazolin sodium hydrate) was used. On the day of surgery, antibiotics were initially administered just before skin incision, and repeated at approximately 3-h intervals if surgery was prolonged. Prophylactic drains were placed routinely, anterior to pancreaticojejunal anastomoses and dorsal to choledochojejunal anastomoses.

All patients were examined for wound and drain conditions during daily surgical team rounds, and results were recorded. Bacterial cultures of drainage fluid were performed routinely on postoperative day (POD) 1 and POD 3. When an SSI was suspected, additional cultures from the wounds or drainage fluid were examined. The treatment of SSIs was in line with advice from the infection control team. Other general descriptions of perioperative management in the authors' institution have been reported previously[9]. Patient consent was obtained for the use of data.

Statistical analysis

All statistical analyses were performed using SPSS® version 19·0 (IBM, Armonk, New York, USA). To evaluate the relationship between each independent factor and the presence of a positive lavage fluid culture, univariable analysis was conducted using the χ^2 test or Fisher's exact test, as appropriate. Some continuous variables were expressed as medians with ranges and compared using the Mann–Whitney *U* test; otherwise, they were dichotomized by reference to median values and compared with the χ^2 test. Variables with $P < 0{\cdot}200$ in univariable analysis were subjected to multivariable logistic regression analysis. $P < 0{\cdot}050$ was considered statistically significant.

Results

A total of 218 consecutive patients underwent pancreaticoduodenectomy in the study interval: 145 men and 73 women with a median age of 69 years (*Table 1*). Forty-six patients (21·1 per cent) had a positive bacterial culture of the lavage fluid and 117 (53·7 per cent) had infected bile. The median interval between biliary drainage and surgical resection was similar in external and internal drainage

Table 1 Patient demographics

	No. of patients ($n = 218$)*
Age (years)†	69 (38–87)
Sex ratio (M : F)	145 : 73
Type of disease	
Pancreatic cancer	101 (46·3)
Biliary cancer	47 (21·6)
IPMN	20 (9·2)
Duodenal cancer	10 (4·6)
Neuroendocrine tumour	5 (2·3)
Other	35 (16·1)
Pancreatic parenchyma	
Soft	136 (62·4)
Hard	82 (37·6)
Biliary drainage	
None	89 (40·8)
Internal	64 (29·4)
External	65 (29·8)

*With percentages in parentheses unless indicated otherwise; †values are median (range). IPMN, intraductal papillary mucinous neoplasm.

Table 2 Surgical outcome according to bacterial culture of lavage fluid

	Lavage bacterial culture		
	Negative ($n = 172$)	Positive ($n = 46$)	P‡
SSI			
Incisional	13 (7·6)	26 (57)	< 0·001
Organ/space	43 (25·0)	32 (70)	< 0·001
Pancreatic fistula grade			
A–C	79 (45·9)	23 (50)	0·623
B/C	48 (27·9)	22 (48)	0·010
Intra-abdominal bleeding	1 (0·6)	2 (4)	0·113
Delayed gastric emptying	16 (9·3)	5 (11)	0·467
Morbidity†			
≥ 3a	74 (43·0)	29 (63)	0·016
≥ 3b	4 (2·3)	5 (11)	0·010
Mortality	1 (0·6)	0 (0)	1·000
Hospital stay (days)*	21 (8–138)	28 (14–128)	0·028§

Values in parentheses are percentages unless indicated otherwise; *values are median (range). †Dindo–Clavien classification[18]. SSI, surgical-site infection. ‡χ^2 test, except §Mann–Whitney U test.

groups (28 (6–66) *versus* 27 (3–131) days respectively; $P = 0·867$). There was no association between duration of biliary drainage and the results of peritoneal lavage culture.

SSIs occurred in 83 (38·1 per cent) of the 218 patients: incisional SSI in 39 (17·9 per cent) and organ/space SSI in 75 (34·4 per cent) (8 had incisional SSI only, 44 had organ/space SSI only, and 31 had both types of SSI). A pancreatic fistula was detected in 102 patients (46·8 per cent): grade A in 32 (14·7 per cent), grade B in 67 (30·7 per cent) and grade C in three patients (1·4 per cent). One patient died from an intra-abdominal bleed resulting from a grade C pancreatic fistula.

Of the 46 patients with a positive lavage culture, 32 (70 per cent) and 33 (72 per cent) had a positive bacterial culture of abdominal drain fluid on POD 1 and 3 respectively, compared with four (2·3 per cent) and ten (5·8 per cent) of the 172 patients with a negative lavage culture ($P < 0·001$ for both POD 1 and POD 3).

Patients with a positive lavage culture had a significantly higher incidence of both incisional SSI (57 per cent *versus* 7·6 per cent in patients with a negative lavage culture; $P < 0·001$) and organ/space SSI (70 *versus* 25·0 per cent respectively; $P < 0·001$) (*Table 2*). Although there was no significant difference in the incidence of all grades (A–C) of pancreatic fistula between the two groups, grade B/C

Table 3 Risk factors for positive bacterial culture of lavage fluid

	Univariable analysis			Multivariable analysis	
	Lavage bacterial culture				
	Negative ($n = 172$)	Positive ($n = 46$)	P†	Odds ratio*	P§
Body mass index (kg/m^2)			0·753		
< 22	89 (51·7)	25 (54)			
≥ 22	83 (48·3)	21 (46)			
Disease			0·194		
Non-pancreatic cancer	97 (56·4)	21 (46)		1·00 (reference)	
Pancreatic cancer	75 (43·6)	25 (54)		1·19 (0·54, 2·59)	0·670
Biliary drainage			< 0·001		
None	81 (47·1)	8 (17)		1·00 (reference)	
External	57 (33·1)	7 (15)		1·31 (0.40, 4.24)	0·657
Internal	34 (19·8)	31 (67)		12·43 (4.94, 34.38)	< 0·001
Pancreas parenchyma			0·655		
Soft	106 (61·6)	30 (65)			
Hard	66 (38·4)	16 (35)			
Bile infection			< 0·001		
No	93 (54·1)	8 (17)		1·00 (reference)	
Yes	79 (45·9)	38 (83)		2·19 (0·71, 11·96)	0·137
Combined colectomy			0·007‡		
No	168 (97·7)	40 (87)		1·00 (reference)	
Yes	4 (2·3)	6 (13)		8·63 (1·79, 41·63)	0·007
Blood loss (ml)			0·205		
< 1000	111 (64·5)	25 (54)			
≥ 1000	61 (35·5)	21 (46)			
Duration of surgery (h)			0·031		
< 8	119 (69·2)	24 (52)		1·00 (reference)	
≥ 8	53 (30·8)	22 (48)		2·41 (1·07, 5·42)	0·034

Values in parentheses are percentages unless indicated otherwise; *values in parentheses are 95 per cent c.i. †χ^2 test, except ‡Fisher's exact test; §logistic regression analysis.

Table 4 Results of bacterial cultures

Bacterial species	Lavage fluid	Incisional SSI	Organ/space SSI	Bile
Enterobacter	16	17	29	25
Enterococcus	13	15	23	34
Klebsiella	4	1	11	28
Bacteroides	4	1	5	2
Staphylococcus	3	3	4	10
Pseudomonas	3	2	6	3
Aeromonas	2	3	2	7
Serratia	2	3	7	2
Streptococcus	2	2	3	18
Escherichia coli	2	0	3	8
Other	5	6	13	27
Total	56	53	106	164

SSI, surgical-site infection.

fistulas were found predominantly in patients with a positive lavage culture. Patients with a positive lavage culture had a significantly higher incidence of postoperative complications, and subsequently a longer hospital stay than those with a negative lavage culture (*Table 2*).

Multivariable analysis revealed that internal biliary drainage (odds ratio (OR) 12.43; $P < 0{\cdot}001$), combined colectomy (OR 8·63; $P = 0{\cdot}007$) and a longer operation (OR 2·41; $P = 0{\cdot}034$) were significant risk factors for a positive lavage bacterial culture (*Table 3*).

A total of 56 bacteria were detected in the 46 patients with a positive lavage culture, 53 bacteria in the 39 patients with incisional SSI, 106 bacteria in the 75 patients with organ/space SSI, and 164 bacteria in the 117 patients with a bile infection (*Table 4*). More than three-quarters of bacteria isolated from the lavage fluid and incisional SSI foci were identical: 42 bacteria were identified in both lavage fluid (42 of 56; 75 per cent) and incisional SSIs (42 of 53; 79 per cent). Only 39 (36·8 per cent) of the 106 bacteria isolated from organ/space SSIs matched those obtained from lavage fluid (39 of 56; 70 per cent). Similarly, only 42 (25·6 per cent) of the 164 bacteria isolated from bile were the same as those obtained from lavage fluid (42 of 56; 75 per cent). In particular, *Enterococcus* and *Enterobacter* were specific species that appeared to spread from bile to lavage fluid (peritoneum) and to SSI foci. Cultures of bile, lavage fluid and incisional SSI foci had a total of 25 bacteria in common, of which eight were *Enterococcus* and 12 were *Enterobacter* species. Cultures of bile, lavage fluid and organ/space SSI foci had 24 bacteria in common, of which seven were *Enterococcus* and 11 *Enterobacter*.

Discussion

In this study, peritoneal lavage was conducted at the end of pancreaticoduodenectomy to reduce the bacterial inoculation in the peritoneal cavity and the presence of substances that may serve as a culture medium for the bacteria. Large-volume peritoneal lavage has been recommended to remove bacteria at the end of surgery and to prevent the subsequent development of SSI[19]. For these reasons, peritoneal lavage with a relatively large volume of normal saline (7000 ml) was conducted in the present study. Nevertheless, more than 20 per cent of bacterial cultures from the final lavage fluid still revealed positive findings for bacteria. In addition, there was a significant relationship between intraoperative bacterial contamination and SSI, and with the development of a grade B/C pancreatic fistula after pancreaticoduodenectomy.

The bacteria cultured in this study indicated that there may be differences in the cause of infection between incisional and organ/space SSIs. Intraoperative bacterial contamination of the abdominal cavity correlated with incisional SSIs, suggesting that intraoperative bacterial contamination was the cause of incisional SSI. It has been reported previously[20] that there is a higher risk of bacterial migration from the abdominal cavity through the fascia to the subcutaneous tissue when the peritoneal cavity is contaminated. In fact, 79 per cent of bacteria isolated from incisional SSIs were the same as those obtained from lavage fluid in the present study. However, only 36·8 per cent of the bacteria isolated from organ/space SSI foci corresponded to those obtained from lavage fluid. Not all of the bacteria causing organ/space SSIs were from intraoperative contamination. Some were due to bacteria arising, for example, from leakage of the pancreatojejunostomy or from a retrograde infection via the drainage tube.

Various reports[5,21–23] have evaluated the perioperative factors that influence the incidence of pancreatic fistula. At present, it is unclear how intraoperative bacterial contamination influences the development of pancreatic fistula. In the present study, the incidence of all grades (A–C) of pancreatic fistula was identical in patients with a positive and those with a negative lavage culture. In contrast, the incidence of grade B/C pancreatic fistula was higher in patients with a positive lavage culture. These results imply that bacterial contamination enhances the progression of a grade A pancreatic fistula to a grade B/C pancreatic fistula. Kobayashi and colleagues[24] reported a similar finding, that infection of drainage fluid on POD 1 is a risk factor for the development of pancreatic fistula. Considering these results, it may be true that intraoperative bacterial contamination is a major cause of grade B/C pancreatic fistula, and prevention of intraoperative bacterial contamination may be necessary to minimize its development.

The present study detected three risk factors for positive lavage culture: a longer operation, combined colectomy

and internal biliary drainage. The first two factors are inevitable in some situations. However, the best approach to biliary drainage is a subject for future investigation. Two retrospective studies[25,26] and a randomized trial[27] concluded that preoperative biliary drainage should not be performed routinely. Although there is no disagreement with this concept, in Japan biliary drains are still placed owing to the relatively long waiting time until surgery. In the present study, internal biliary drainage was associated with a higher incidence of bile infection compared with no biliary drainage and external drainage (data not shown). This might have contributed indirectly to the intraoperative bacterial contamination. Jagannath and co-workers[28] reported that a positive intraoperative bile culture was associated with infectious complications. In this context, it has been reported[29] that PTBD may reduce the risk of biliary infection. However, PTBD catheter-tract cancer recurrence was detected in 5·2 per cent of patients with cholangiocarcinoma undergoing resection[30], suggesting that PTBD should be avoided. Recently, ENBD in patients with perihilar cholangiocarcinoma was reported[31] to be an effective and suitable preoperative drainage method for perihilar cholangiocarcinoma. As the present results suggest that ENBD may be more effective in preventing SSI than internal drainage, a randomized study comparing these procedures is planned.

Disclosure

The authors declare no conflict of interest.

References

1 Kimura W, Miyata H, Gotoh M, Hirai I, Kenjo A, Kitagawa Y *et al*. A pancreaticoduodenectomy risk model derived from 8575 cases from a national single-race population (Japanese) using a web-based data entry system: the 30-day and in-hospital mortality rates for pancreaticoduodenectomy. *Ann Surg* 2014; **259**: 773–780.

2 Conlon KC, Labow D, Leung D, Smith A, Jarnagin W, Coit DG *et al*. Prospective randomized clinical trial of the value of intraperitoneal drainage after pancreatic resection. *Ann Surg* 2001; **234**: 487–493.

3 Pisters PW, Hudec WA, Hess KR, Lee JE, Vauthey JN, Lahoti S *et al*. Effect of preoperative biliary decompression on pancreaticoduodenectomy-associated morbidity in 300 consecutive patients. *Ann Surg* 2001; **234**: 47–55.

4 Yeo CJ, Cameron JL, Lillemoe KD, Sohn TA, Campbell KA, Sauter PK *et al*. Pancreaticoduodenectomy with or without distal gastrectomy and extended retroperitoneal lymphadenectomy for periampullary adenocarcinoma, part 2: randomized controlled trial evaluating survival, morbidity, and mortality. *Ann Surg* 2002; **236**: 355–366.

5 Adam U, Makowiec F, Riediger H, Schareck WD, Benz S, Hopt UT. Risk factors for complications after pancreatic head resection. *Am J Surg* 2004; **187**: 201–208.

6 Schmidt CM, Powell ES, Yiannoutsos CT, Howard TJ, Wiebke EA, Wiesenauer CA *et al*. Pancreaticoduodenectomy: a 20-year experience in 516 patients. *Arch Surg* 2004; **139**: 718–725.

7 Kazanjian KK, Hines OJ, Eibl G, Reber HA. Management of pancreatic fistulas after pancreaticoduodenectomy: results in 437 consecutive patients. *Arch Surg* 2005; **140**: 849–854.

8 Kimura F, Shimizu H, Yoshidome H, Ohtsuka M, Kato A, Yoshitomi H *et al*. Increased plasma levels of IL-6 and IL-8 are associated with surgical site infection after pancreaticoduodenectomy. *Pancreas* 2006; **32**: 178–185.

9 Sugiura T, Uesaka K, Ohmagari N, Kanemoto H, Mizuno T. Risk factor of surgical site infection after pancreaticoduodenectomy. *World J Surg* 2012; **36**: 2888–2894.

10 Platell C, Papadimitriou JM, Hall JC. The influence of lavage on peritonitis. *J Am Coll Surg* 2000; **191**: 672–680.

11 Qadan M, Dajani D, Dickinson A, Polk HC Jr. Meta-analysis of the effect of peritoneal lavage on survival in experimental peritonitis. *Br J Surg* 2010; **97**: 151–159.

12 Minervini S, Bentley S, Youngs D, Alexander-Williams J, Burdon DW, Keighley MR. Prophylactic saline peritoneal lavage in elective colorectal operations. *Dis Colon Rectum* 1980; **23**: 392–394.

13 Ambrose NS, Donovan IA, Derges S, Minervini S, Harding LK. The efficacy of peritoneal lavage at elective abdominal operations. *Br J Surg* 1982; **69**: 143–144.

14 Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG. CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. *Infect Control Hosp Epidemiol* 1992; **13**: 606–608.

15 Centers for Disease Control. *CDC/NHSN Surveillance Definitions for Specific Types of Infections*; 2015. http://www.cdc.gov/nhsn/PDFs/pscManual/17pscNosInfDef_current.pdf [accessed 19 February 2015].

16 Bassi C, Dervenis C, Butturini G, Fingerhut A, Yeo C, Izbicki J *et al*. Postoperative pancreatic fistula: an international study group (ISGPF) definition. *Surgery* 2005; **138**: 8–13.

17 Wente MN, Bassi C, Dervenis C, Fingerhut A, Gouma DJ, Izbicki JR *et al*. Delayed gastric emptying (DGE) after pancreatic surgery: a suggested definition by the International Study Group of Pancreatic Surgery (ISGPS). *Surgery* 2007; **142**: 761–768.

18 Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 2004; **240**: 205–213.

19 Sugimoto K, Hirata M, Takishima T, Ohwada T, Shimazu S, Kakita A. Mechanically assisted intraoperative peritoneal lavage for generalized peritonitis as a result of perforation of the upper part of the gastrointestinal tract. *J Am Coll Surg* 1994; **179**: 443–448.

20 Ruiz-Tovar J, Santos J, Arroyo A, Llavero C, Armañanzas L, López-Delgado A *et al*. Effect of peritoneal lavage with clindamycin–gentamicin solution on infections after elective colorectal cancer surgery. *J Am Coll Surg* 2012; **214**: 202–207.
21 Wada K, Traverso LW. Pancreatic anastomotic leak after the Whipple procedure is reduced using the surgical microscope. *Surgery* 2006; **139**: 735–742.
22 Poon RT, Fan ST, Lo CM, Ng KK, Yuen WK, Yeung C *et al*. External drainage of pancreatic duct with a stent to reduce leakage rate of pancreaticojejunostomy after pancreaticoduodenectomy: a prospective randomized trial. *Ann Surg* 2007; **246**: 425–433.
23 Sato N, Yamaguchi K, Chijiiwa K, Tanaka M. Risk analysis of pancreatic fistula after pancreatic head resection. *Arch Surg* 1998; **133**: 1094–1098.
24 Kobayashi S, Gotohda N, Kato Y, Takahashi S, Konishi M, Kinoshita T. Infection control for prevention of pancreatic fistula after pancreaticoduodenectomy. *Hepatogastroenterology* 2013; **60**: 876–882.
25 Povoski SP, Karpeh MS Jr, Conlon KC, Blumgart LH, Brennan MF. Association of preoperative biliary drainage with postoperative outcome following pancreaticoduodenectomy. *Ann Surg* 1999; **230**: 131–142.
26 Sewnath ME, Birjmohun RS, Rauws EA, Huibregtse K, Obertop H, Gouma DJ. The effect of preoperative biliary drainage on postoperative complications after pancreaticoduodenectomy. *J Am Coll Surg* 2001; **192**: 726–734.
27 van der Gaag NA, Rauws EA, van Eijck CH, Bruno MJ, van der Harst E, Kubben FJ *et al*. Preoperative biliary drainage for cancer of the head of the pancreas. *N Engl J Med* 2010; **362**: 129–137.
28 Jagannath P, Dhir V, Shrikhande S, Shah RC, Mullerpatan P, Mohandas KM. Effect of preoperative biliary stenting on immediate outcome after pancreaticoduodenectomy. *Br J Surg* 2005; **92**: 356–361.
29 Kajiwara T, Sakamoto Y, Morofuji N, Nara S, Esaki M, Shimada K *et al*. An analysis of risk factors for pancreatic fistula after pancreaticoduodenectomy: clinical impact of bile juice infection on day 1. *Langenbecks Arch Surg* 2010; **395**: 707–712.
30 Takahashi Y, Nagino M, Nishio H, Ebata T, Igami T, Nimura Y. Percutaneous transhepatic biliary drainage catheter tract recurrence in cholangiocarcinoma. *Br J Surg* 2010; **97**: 1860–1866.
31 Kawashima H, Itoh A, Ohno E, Itoh Y, Ebata T, Nagino M *et al*. Preoperative endoscopic nasobiliary drainage in 164 consecutive patients with suspected perihilar cholangiocarcinoma: a retrospective study of efficacy and risk factors related to complications. *Ann Surg* 2013; **257**: 121–127.