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ORIGINAL ARTICLE

Migration of Internal Pancreaticojejunostomy Stents into the Bile Ducts in Patients Undergoing Pancreatoduodenectomy

So Hyun Park[1] · Jin Hee Kim[1] · Seung Yeon Noh[1] · Jae Ho Byun[1] · Seung Soo Lee[1] · Hyoung Jung Kim[1] · Seong Ho Park[1] · Sung Koo Lee[2] · Dae Wook Hwang[3] · Song Cheol Kim[3] · Duck Jong Han[3] · Moon-Gyu Lee[1]

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Abstract

Purpose To investigate the incidence, complications, and risk factors of the migration of internal pancreaticojejunostomy (PJ) stents into the bile ducts in patients undergoing pancreatoduodenectomy.

Methods Postoperative computed tomography (CT) and clinical data of 802 patients with CT-detectable internal PJ stents were reviewed to assess the occurrence of stent migration into the bile ducts and stent-induced complications with their clinical significance. Risk factors for stent migration and stent-induced complications were determined.

Results Stent migration into the bile ducts occurred in 135 patients (16.8 %); 40 of these (29.6 %) showed stent-induced complications including bile duct stricture, stone, and liver abscess. Clinically significant complications were identified in only eight patients. Neither the stent length nor diameter was associated with stent migration. A small stent diameter, peripheral location of the stent, absence of stent remigration from the bile ducts to the intestine, and longer stent retention time in the bile ducts were risk factors of stent-induced complications.

Conclusions The incidence of internal PJ stent migration into the bile ducts was 16.8 %. Migrated stents frequently caused complications, although they were mostly subclinical. Stent-induced complications were associated with stent diameter and location, stent remigration to the intestine, and stent retention time in the bile ducts.

Keywords Pancreaticojejunostomy · Internal stent · Pancreatoduodenectomy · Migration · Bile ducts

✉ Jin Hee Kim
kimjhrad@amc.seoul.kr

[1] Department of Radiology and Research Institute of Radiology, Asan Medical Center, College of Medicine, University of Ulsan, 88 Olympic-ro, 43-gil, Songpa-Gu, Seoul 138-736, South Korea

[2] Department of Internal Medicine, Asan Medical Center, College of Medicine, University of Ulsan, 88 Olympic-ro, 43-gil, Songpa-Gu, Seoul 138-736, South Korea

[3] Department of Surgery, Asan Medical Center, College of Medicine, University of Ulsan, 88 Olympic-ro, 43-gil, Songpa-Gu, Seoul 138-736, South Korea

Introduction

Pancreatoduodenectomy is the procedure of choice for resectable cancers and selected benign diseases of the periampullary region. Despite the recent decline in postoperative morbidity and mortality, pancreatic fistula is still recognized as the most frequent major post-pancreatoduodenectomy complication and can cause potentially life-threatening conditions such as abscess, sepsis, or bleeding, and even death.[1–5]

Internal stenting of the pancreaticojejunostomy (PJ) has been widely used to reduce the pancreatic fistula rate, although its efficacy is still debatable.[6–11] Internal PJ stents are generally assumed to pass spontaneously into the small intestine and eventually pass uneventfully through the rectum. However, this assumption does not always hold true because various stent-induced complications, including bile duct strictures and stones, liver abscess, intestinal obstruction, and intestinal perforation, have been reported to occur during stent

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passage through the intestine.[12–18] A considerable proportion of these complications has been associated with stent migration into the bile ducts.[12–15] However, to the best of our knowledge, little is known about stent migration into the bile ducts because the literature is limited to case reports and no study has investigated this issue in depth in a large series. We therefore performed our current study to systematically investigate the incidence, complications, and associated risk factors of the migration of internal PJ stents into the bile ducts in patients undergoing pancreatoduodenectomy.

Materials and Methods

Study Population

This retrospective study was approved by our institutional review board, and patient informed consent was waived. Through a search of our medical database, we identified 2190 patients who underwent a pancreatoduodenectomy at our institution between January 2009 and December 2013 (Fig. 1). Inclusion criteria were as follows: (a) the presence of an internal PJ stent that was identifiable on computed tomography (CT) and (b) the availability of CT follow-up data of 1 month or more after surgery. The presence of an internal PJ stent on CT was determined in consensus by two radiologists (with 12 and 5 years of clinical experience in abdominal CT interpretation, respectively). Finally, 802 patients (486 men and 316 women; mean age±standard deviation [SD], 61±10.6 years [range, 24–88 years]) were included. These patients underwent pancreatoduodenectomy due to pancreatic cancer (n=313), bile duct cancer (n=197), ampulla of Vater cancer (n=137), duodenal cancer (n=29), other periampullary malignancies (n=24), intraductal papillary mucinous neoplasm (n=38), neuroendocrine (n=18) or solid pseudopapillary (n=11) tumors of the pancreas, and other benign diseases (n=35).

Internal PJ Stent Placement

A silastic stent was appropriately placed across the anastomosis during the duct-to-mucosa PJ procedure. The stent was secured in place with a single, absorbable suture to the pancreas. Surgeons took care to avoid narrowing the stent lumen. The stent diameter (2–10 Fr, outer diameter) was determined according to the diameter of the remaining pancreatic duct. Because the stent length was not commercially standardized, stents that were originally too long were cut to the appropriate length by surgeons. The surgeons usually preferred a short length (typically, 4–6 cm). However, longer stents were sometimes used if necessary at the discretion of the surgeons.

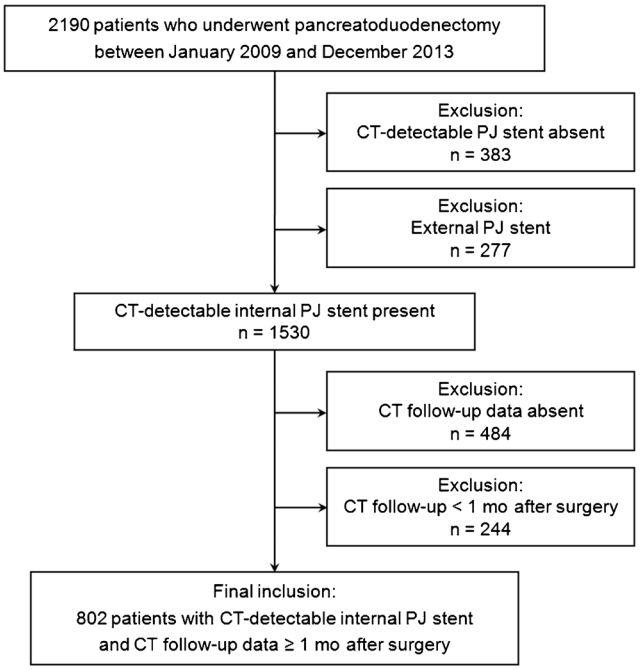

Fig. 1 Flow diagram of the study population

Use of CT in Stent Assessment

Because the silastic stents used in the PJ were faintly radiopaque, they appeared as slightly high-density linear structures on CT (Figs. 2 and 3). Therefore, it was difficult to distinguish them from the surrounding organs on contrast-enhanced images. Hence, unenhanced images were primarily used to identify the stents, and contrast-enhanced images were adjunctively used to confirm an accurate anatomic location of the stents. Because CT scans obtained without unenhanced images were not used, all CT scans used in this study refer to those including unenhanced images.

CT scans from the liver dome to the symphysis pubis were performed with 16-, 64- or 128-channel multidetector scanners. The slice thickness was 3–5 mm. The first postoperative CT was mostly obtained within 2 weeks after surgery (775 of 802). Thereafter, follow-up CT was performed as deemed necessary. The total number of CT scans used in this study ranged from 2 to 28 (mean, 5.3). The postoperative CT follow-up duration ranged from 30 to 2332 days (mean, 475 days).

Assessment of Stent Migration

The same radiologists reviewed all follow-up CT scans to determine in consensus the stent migration. When the stent completely detached from the PJ, it was defined as "1st migration (M1)." The stent was considered to be in position if any portion of it remained in the PJ. Proximal migration into the remnant pancreatic duct was excluded from M1. If the stent was not found in any site of the abdomen, then it was

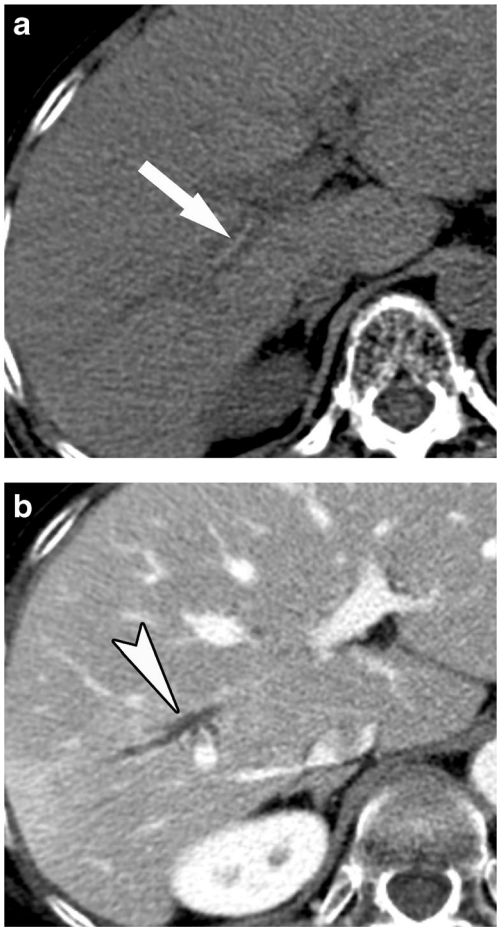

Fig. 2 A 74-year-old woman who underwent pancreatoduodenectomy due to intraductal papillary mucinous neoplasm of the pancreas. **a** Unenhanced CT image obtained 4 years and 6 months after surgery demonstrates a migrated internal PJ stent that appears as a slightly high-density linear structure (*arrow*) in the right posterior bile duct. **b** Contrast-enhanced CT image demonstrates a focal bile duct stricture with upstream dilatation (*arrowhead*) near the migrated stent

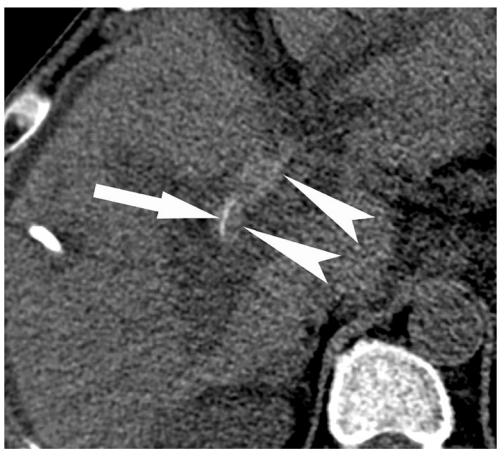

Fig. 3 A 64-year-old man who underwent pancreatoduodenectomy due to pancreatic cancer. Unenhanced CT image obtained 2 years after surgery shows a migrated stent (*arrow*) in the right main duct that is surrounded by stones (*arrowheads*)

considered to have passed through the rectum by defecation following M1. When the stent was seen in the bile ducts, regardless of whether it was located partially or totally in the bile ducts, it was defined as "2nd migration (M2)." Meanwhile, internal stents had been sometimes placed in biliojejunostomy as well as in PJ. Thus, the reviewers were careful not to mistake biliojejunostomy stents for migrated PJ stents when a stent was detected in the bile ducts.

Detailed Analysis of Patients with M2

For patients with M2, the time interval between surgery and M2 occurrence was calculated. We also evaluated the temporal relationship between M1 and M2 occurrence. The date at which M1 or M2 was first detected on CT was considered the M1 or M2 occurrence time. The stent location (based on proximal/upper tip position) was determined as one of the following regions: common duct, main duct, and peripheral duct (i.e., second-order branch or more peripheral). For patients who had post-M2 follow-up CT, the following data were obtained: (i) stent movability, that is, whether the migrated stent was movable or fixed within the bile ducts after M2; if the stent was obviously movable within the bile ducts (e.g., from the common duct to the peripheral duct), the region where the stent stayed longest was considered the stent location; (ii) occurrence of "3rd migration (M3)," which was defined as a condition where the stent in the bile ducts remigrated downwardly back to the intestine; and (iii) stent retention time in the bile ducts after M2, that is, for patients with M3, the interval between the two respective CT examinations that revealed M2 and M3 presence and, for patients without M3, the interval between the CT examination that revealed M2 presence and the last follow-up CT.

Assessment of Stent-Induced Complications in Patients with M2

The CT reviewers determined in consensus whether stent-induced complications (i.e., bile duct stricture, bile duct stone, or liver abscess) occurred in patients with M2. Stent-induced bile duct stricture was defined as the presence of focal narrowing in the bile ducts where the migrated stent was located and upstream duct dilatation. A stent-induced bile duct stone was defined as the presence of intraductal, non-enhancing, hyperdense lesions that surrounded the migrated stent. If the bile duct stricture or stone was identified to be already present on CT scans that were obtained before M2 occurrence, then it was not considered to be a stent-induced complication. Stent-induced liver abscess was defined as a newly developed cyst-like hypodense liver nodule/mass with peripheral enhancement and surrounding hyperemia, along with typical clinical features including fever and leukocytosis in patients who satisfied the following conditions: the liver nodule/mass

and the migrated stent appeared in the same segment/lobe, and improvement of the liver lesion after antibiotic therapy and/or drainage procedure was identified on follow-up CT. Meanwhile, when evaluating patients with liver metastasis, the reviewers tried not to confuse metastasis-related abnormalities with stent-induced complications. If it was difficult to distinguish these two conditions, the lesion was considered to be metastasis related.

For patients with stent-induced complications, the time interval between M2 occurrence and CT-determined complication onset was calculated. In addition, their medical records were reviewed to determine whether the complications were clinically significant or subclinical. A clinically significant complication was defined as a condition that required admission for interventional or medical treatment due to the patient's symptoms or laboratory abnormalities directly associated with the complications. They were otherwise regarded as subclinical complications.

Assessment of M2-Associated Factors

To evaluate if stent length or diameter was associated with an occurrence of M2 following M1, these data were compared between patients with both M1 and M2 and those with M1 but without M2. The stent length was categorized as "short," "medium," and "long" based on its distal tip position as follows: short, if the tip was located near the PJ and far proximal to the biliojejunostomy; medium, if the tip was located around the biliojejunostomy; and long, if the tip was located far distal to the biliojejunostomy. The stent diameter was categorized as "small" (<4 Fr), "medium" (4–7 Fr), and "large" (>7 Fr) by referring to the surgical records.

Assessment of Risk Factors for Stent-Induced Complications

To assess risk factors of stent-induced complications in patients with M2, the following variables were compared between patients with complications and those without complications: patient age and sex; stent-related data including its length, diameter, location, movability, and retention time in the bile ducts; and presence of M3. Only patients with available follow-up CT data after M2 were included in this analysis. The CT follow-up duration after M2 was also compared between the two groups.

Statistical Analysis

For statistical comparisons regarding M2-associated factors and stent-induced complication-associated factors, the Fisher's exact test or unpaired Student's *t* test was used, as appropriate. For variables with p values<0.05 as determined by univariate analysis, a further multivariate binary logistic regression analysis was performed using the backward likelihood ratio method to determine factors independently associated with stent-induced complications. A p value<0.05 was considered statistically significant. SPSS for Windows, version 21.0 (SPSS Inc., Chicago, IL), was used for all statistical analyses.

Results

Incidence of M2 Occurrence and Its Details

M2 occurred in 135 of the 802 study patients (16.8 %). The time interval between surgery and M2 occurrence ranged from 7 to 1800 days (mean±SD, 285±311 days). Most incidences of M2 (102 of 135, 75.6 %) occurred within 1 year after surgery. The cumulative incidence of M2 at 1, 6, 12, and 36 months was 1.7 % (n=14), 7.9 % (n=63), 12.7 % (n=102), and 16.5 % (n=132), respectively. As for the temporal relationship between M1 and M2, M2 occurred concurrently with M1 in 90 patients (66.7 %) and M2 followed M1 in 28 (20.7 %). In the remaining 17 patients, M2 occurred first, followed by M1 (n=8, 5.9 %), or only M2 occurred without M1 (n=9, 6.7 %); these outcomes were possible because these patients had medium- (n=11) or long-length (n=6) stents. The stents were most commonly located in the peripheral duct (n=76, 56.3 %), followed by the main duct (n=38, 28.1 %) and the common duct (n=21, 15.6 %). Among 109 patients with post-M2 follow-up CT data, the stent was obviously movable within the bile ducts in 31 (28.4 %). M3 occurred in 50 patients (45.9 %). The stent retention time in the bile ducts ranged from 5 to 1725 days (mean±SD, 380±413 days).

Stent-Induced Complications in Patients with M2

Stent-induced complications were identified in 40 of 135 patients with M2 (29.6 %) (Table 1). A stent-induced bile duct stricture occurred in 37 patients (27.4 %). Of these, 27 had only a bile duct stricture, whereas the remaining 10 had a bile duct stricture together with stones (n=7) or a liver abscess (n=3). The interval between M2 occurrence and CT-determined complication onset ranged from 0 to 329 days (mean±SD, 86±129 days). Of the 135 patients with M2, 8 (5.9 %) experienced clinically significant complications (Table 1). Of these eight patients, two with bile duct stricture underwent biliary drainage procedures due to their symptoms and liver function test abnormalities, and one patient underwent a retrievable metallic stent placement (Fig. 2); three symptomatic patients with both bile duct stricture and stones underwent repeated biliary interventional procedures including external/internal drainage and cholangioscopic stone removal (Fig. 3); and three patients with liver abscess recovered uneventfully following antibiotic therapy alone (n=2) or with abscess

Table 1 Stent-induced complications in 40 patients with M2

Complications	Clinically significant (n=8)	Subclinical (n=32)
Bile duct stricture alone	2	25
Bile duct stones alone	0	3
Stricture + stones	3	4
Stricture + liver abscess	3	0

drainage (n=1). None of these eight patients died from the stent-induced complications during the study period.

M2-Associated Factors

A comparison of stent length and diameter between the 126 patients with M1 and M2 and the 418 patients with M1 without M2 is presented in Table 2. Neither stent length nor diameter was found to be associated with M2 occurrence in patients with M1 ($p \geq 0.099$).

Risk Factors for Stent-Induced Complications

Among the 135 patients with M2, 109 cases with available post-M2 follow-up CT data were included in this analysis. The results of univariate and multivariate analyses to assess the risk factors of stent-induced complications are summarized in Tables 3 and 4, respectively. The proportion of small-diameter stents was significantly greater in patients with complications than in those without complications, whereas the opposite was seen for medium-diameter stents (p=0.007). The stents were located in the peripheral duct in most (90 %) of the patients with complications, whereas none of the 15 patients with stents in the common duct experienced complications (p<0.001). M3 occurred less frequently in patients with complications than in those without complications (p=0.001). The stent retention time in the bile ducts was significantly longer in patients with complications than in those without complications (p=0.013). Patient age and sex, and stent length and movability, did not significantly differ between the two groups ($p \geq 0.843$). Multivariate analysis identified peripheral stent location, absence of M3, and longer stent retention time in the bile ducts as being independently associated with stent-induced complications ($p \leq 0.013$), with odds ratios ranging from 1.06 to 11.73.

Table 2 M2-associated factors in 544 patients with M1

	M2		p value
	Present (n=126) (%)	Absent (n=418) (%)	
Stent length			0.419
Short	99 (78.6)	331 (79.2)	
Medium	19 (15.1)	49 (11.7)	
Long	8 (6.3)	38 (9.1)	
Stent diameter			0.099
Small	25 (19.8)	104 (24.9)	
Medium	49 (38.9)	121 (28.9)	
Large	52 (41.3)	193 (46.2)	

Discussion

Our study is the first to systematically investigate the incidence, complications, and risk factors of the migration of internal PJ stents into the bile ducts in patients undergoing pancreatoduodenectomy. The incidence of stent migration into the bile ducts in our study was 16.8 % (135 of 802), which was somewhat higher than the 7 % rate (4 of 57) reported in a previous study.[13] This difference may be due to several factors. First, as the previous study included a much smaller number of patients, they may have been subject to sampling bias. Second, our study included only patients for whom follow-up CT data of 1 month or more after surgery were available. Our incidence would have been approximately 9 % if all patients (n=1530) with CT-detectable internal PJ stents were considered, regardless of the presence or duration of follow-up CT data. The mechanism for PJ stent migration into the bile ducts is unknown but, conceivably, the stent tip might be caught at the site of biliojejunostomy by chance during distal migration after M1, that is, stent detachment from the PJ. In our study, both the stent diameter and length were not associated with its migration into the bile ducts, and this result was somewhat unexpected because we speculated that a thinner stent would be more easily caught by the small opening of the biliojejunostomy. Interestingly, medium- and long-length stents sometimes migrated into the bile ducts even without detachment from the PJ as the distal tip of these stents can be located in the vicinity of the biliojejunostomy even when the proximal tip is in position. This finding may be worthy of consideration when surgeons determine the stent length.

The high incidence (29.6 %, 40 of 135) of stent-induced complications in patients with migrated PJ stents in the bile ducts was a noticeable result of our study. The occurrence of these complications may be explained by the following two mechanisms. The first mechanism involves direct physical stimulation of the bile duct wall by the migrated stent. In many previous studies,[14, 19–23] pancreatic and bile duct stents have been reported to cause ductal inflammation and fibrosis, eventually leading to ductal stricture, chronic pancreatitis, and cholangitis. These results may support our conjecture. The second plausible mechanism involves inflammatory changes associated with bile stasis caused by the stent obstruction. Obstruction is a well-known complication of biliary stents.[24, 25] The stent patency in the bile ducts can be limited by various

Table 3 Univariate analysis to identify risk factors for stent-induced complications in patients with M2

	Stent-induced complication		*p* value
	Present (n=40)[a] (%)	Absent (n=69)[a] (%)	
Age (year)[b]	60.6±9.0 [43–78]	60.6±11.3 [33–88]	0.976
Sex			0.843
Man	22 (55)	36 (52.2)	
Woman	18 (45)	33 (47.8)	
CT follow-up duration (day)[b]	560±500 [24–1725]	506±532 [5–1874]	0.604
Stent length			0.891
Short	28 (70)	51 (73.9)	
Medium	9 (22.5)	13 (18.8)	
Long	3 (7.5)	5 (7.2)	
Stent diameter			0.007
Small	14 (35)	8 (11.6)	
Medium	10 (25)	33 (47.8)	
Large	16 (40)	28 (40.6)	
Stent location			<0.001
Common duct	0 (0)	15 (21.7)	
Main duct	4 (10)	24 (34.8)	
Peripheral duct	36 (90)	30 (43.5)	
Stent movability			1.000
Movable	11 (27.5)	20 (29)	
Fixed	29 (72.5)	49 (71)	
M3			0.001
Present	10 (25)	40 (58)	
Absent	30 (75)	29 (42)	
Stent retention time (day)[b]	521±493 [24–1725]	298±336 [5–1694]	0.013

[a] 109 patients with available follow-up CT data after M2.

[b] Mean± SD [range].

factors, including bacteria, protein, bile viscosity, and stent properties. As a result, the stent lumen is obstructed by the deposition of sludge containing a bacterial biofilm and calcium crystals.[24] In our study, bile duct stones occurred in the absence of stricture in three patients. This finding may suggest that migrated stents themselves can serve as a nidus for stone formation.

Table 4 Multivariate analysis to identify risk factors for stent-induced complications in patients with M2

Factors[a]	*p* value	Odds ratio (95 % CI)
Small stent diameter	NA	NA
Peripheral duct stent location	<0.001	11.73 (3.41–40.28)
Absence of M3	0.002	5.03 (1.79–14.09)
Longer stent retention time (month)	0.013	1.06 (1.01–1.10)

NA not available (values for non-significant factors, as determined by multivariate analysis, are not presented).

[a] *p* values less than 0.05 by univariate analysis.

Despite the strikingly high complication rate in our cohort, a reassuring fact is that patients with clinically significant complications comprised only 5.9 % of cases (8 of 135) and the overall incidence of such serious adverse events for all patients was less than 1 % (8 of 802). In particular, most (92.6 %, 25 of 27) of the patients with bile duct stricture alone did not have any clinically significant symptoms or laboratory abnormalities directly associated with the stricture. Moreover, none of our patients died from a stent-induced complication. In the English language medical literature, there has been only one patient who died from a migrated stent-induced complication.[13] The patient died due to multiorgan failure that was presumably associated with a liver abscess. However, in that case, a real causal relationship between the migrated stent and the liver abscess or death is unclear because the patient had carcinoma recurrence at the hepatic hilum.

Our study revealed that a small stent diameter, peripheral location of the stent, absence of M3 (i.e., remigration of the stent from the bile ducts to the intestine), and longer stent retention time in the bile ducts were risk factors for stent-induced complications. The latter three variables were identified to be independent factors in multivariate analysis and a peripheral location was the most significant factor with the highest odds ratio. These risk factors and the occurrence of complications are suggested to have a cause-and-effect relationship with one another, forming a vicious cycle. In other words, a thin stent may easily migrate to the peripheral duct; a thin stent migrated to the peripheral duct is likely to be vulnerable to obstruction and may lead to ductal inflammation; an inflamed duct may gradually become narrow; a narrowed duct may fix the stent to the duct for a long time; a stent that stays for a long time in the inflamed duct may ultimately worsen the inflammation.

Based on the identification of these specific risk factors of stent-induced complications, current clinical practices may need to be modified. First, it may be prudent to place the largest diameter stent possible when creating the PJ to reduce the potential risk of complications. Second, if a stent that has migrated to the bile ducts is detected on postoperative CT, then it may be necessary to shorten the subsequent follow-up interval to monitor whether complications occur, unless the stent is identified to disappear from the bile ducts, because our data suggest that the complication risk may increase by 6 % every month. Third, a preventive retrieval of the migrated stent may need to be seriously considered when a thin stent is fixed in the peripheral duct for a long time.

Given the appreciable incidences of internal PJ stent migration into the bile ducts as well as its related complications, exteriorizing the PJ stent can be a good solution to internal stent-related problems as well as to decrease the rate of

postoperative pancreatic fistulas. Compared with internal stents, external stents have been purported to be more effective at diverting pancreatic juice away from the anastomosis.[26-28] However, external stents are uncomfortable for patients and have the potential for inadvertent removal.[23] Although it is still debated whether internal or external stents are more efficacious, more recent studies seem to advocate external stents[10, 11, 26-30] than internal stents[6, 7].

Another important stent-related issue revealed by our study is that it was not easy to detect current silastic stents using CT due to their faint radio-opacity, as mentioned above. Indeed, in clinical practice, CT failed to detect migrated stents in the bile duct in almost all cases when referring to the CT interpretation reports, and the stents could only be identified on a focused retrospective review. Therefore, it may be necessary to make silastic stents more radio-opaque to be readily discernible on CT, which will facilitate a straightforward diagnosis of stent migration as well as its appropriate management.

A potential criticism of this study is that the CT follow-up intervals and the total follow-up durations varied considerably among the patients due to the retrospective study design and relatively long study period.

Conclusion

The incidence of internal PJ stent migration into the bile ducts is about 17 %. A migrated stent frequently causes complications, although clinically significant complications are relatively rare. Stent-induced complications are associated with stent diameter and location, remigration of the stent from the bile ducts to the intestine, and stent retention time in the bile ducts.

Conflicts of Interest The authors declare that they have no competing interests.

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