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ORIGINAL ARTICLE – PANCREATIC TUMORS

Readmission After Pancreatic Resection: Causes and Causality Pattern

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ABSTRACT

Background. Readmission rates have been targeted for cost/reimbursement control. Our goal was to identify causes for readmission and delineate the pattern of early and late readmission.

Methods. Between 2011 and 2012, a total of 490 patients underwent pancreaticoduodenectomy, distal pancreatectomy or central pancreatectomy. Logistic regression was used to identify predictors of readmission. *K*-medoids clustering was performed to identify the major readmission subgroups.

Results. Median postoperative length of stay (LOS) was 7 days, and the 30- and 90-day readmission rates were 23 and 29 %, respectively. The most common cause for 30-day readmissions was procedure-related infections (58 %), while the most common cause for 31–90-day readmissions was failure to thrive and chemotherapy-related symptoms (38 %). Independent predictors of 30-day readmissions were central pancreatectomy, discharge with a drain, pancreatic duct <3 mm, previous abdominal surgery, and postoperative LOS. Independent predictors for 31–90-day readmissions were age and preoperative serum carcinoembryonic antigen. Cancer-related covariates were more common in the 31–90-day readmission group. Postoperative carbohydrate antigen 19-9 levels were twofold higher in the 31–90-day readmission group compared with the no readmission group ($p = 0.03$). *K*-medoids clustering identified a subgroup where 74 % of readmissions occur at a median of 7 days after discharge.

Conclusions. Readmissions after pancreatic operations are procedure-related in the first 30 days, but those after this period are influenced by the natural history of the underlying diagnosis. The readmission penalty policy should account for the timing of readmission and the natural history of the underlying disease and procedure. Early follow-up for patients at high risk for readmission may minimize early readmissions.

Readmission rates have attracted the attention of policy makers as a potential target to lower healthcare costs. The readmission rate of Medicare beneficiaries within 30 days is 17.6 %, at an estimated cost of $15 billion.[1] The Center for Medicare and Medicaid Services (CMS)[2] requires reporting of 30-day hospital readmission rates for pneumonia, heart failure, and myocardial infarction. The Medicare Payment Advisory Commission[1] has proposed penalties for hospitals with high readmissions rates. Expansion of the readmission penalty program to include surgical procedures has been suggested by CMS, and Medicare has defined a 90-day timeframe global fee for major surgery.[3]

The proposed penalty policy and the 90-day global period that Medicare developed for major surgery might not be appropriate for certain operations. Studies demonstrate that patients undergoing pancreatic operations are expected to have higher readmission rates, since they are older, with more comorbidities, and undergo complex procedures.[4–7] The aggressive biology of pancreatic cancer and widespread use of adjuvant treatment act as confounders, since disease progression or adjuvant treatment

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can result in readmission.[5,8] As providers are pushed to lower the readmission rate by a punitive policy, an inverse relationship between length of stay (LOS) and readmission rate was proposed.[9]

The studies of readmissions evaluate factors in three tiers: patient-, surgeon-, and hospital-related predictors. Tsai et al.[10] analyzed Medicare data relating to readmissions after major surgery and demonstrated that hospitals with high surgical volume and low surgical mortality have lower rates of surgical readmission. Hyder et al.[11] studied the Surveillance, Epidemiology, and End Results (SEER)-Medicare data and concluded that the largest contributor to readmission was patient-related preoperative comorbidities.

It is our premise that analyses of variables related to readmission should be conducted at high-volume centers with high-volume surgeons and low mortality rates in order to establish the appropriate benchmarks. The objective of the current study was to identify causes for readmission after common pancreatic operations and delineate the unique pattern of early and late readmissions.

METHODS

Study Design

The Institutional Review Board approved the query of a prospectively maintained pancreatic resection database to identify patients who had undergone a pancreatic resection for any diagnosis between January 2011 and December 2012. We identified 550 adult patients, from which we excluded any patient who underwent a procedure other than pancreaticoduodenectomy, distal pancreatectomy or central pancreatectomy. A total of 490 patients were included. The extent and definitions of the prospectively collected data, including morbidity, were previously reported.[12–14] Readmissions were recorded up to 90 days after discharge from the index admission. Three groups were constructed: Group 1 (30-day group), patients readmitted within the first 30 days but not necessarily only during the first 30 days, Group 2 (31–90-day group), patients readmitted only between 31 and 90 days after discharge, and Group 3 (90-day group), patients readmitted within the first 90 days after discharge. Patient A who is readmitted 2 weeks after discharge will be counted in the 30- and 90-day groups. Patient B who is readmitted 2 months after discharge will be counted in the 31–90- and 90-day groups. Patient C who is readmitted both 2 weeks and 2 months after discharge will be counted in the 30- and 90-day groups. As potential predictors for readmission, only complications diagnosed during the index admission were analyzed.

Additionally, the pancreatic resection database was queried for the postoperative LOS of patients subjected to pancreatoduodenectomy or distal pancreatectomy in the last three decades.

TABLE 1 Pathological diagnoses of resected lesions ($n = 490$)

Primary pathologic diagnosis	Number of patients (%)
Malignant tumors	381 (78)
Adenocarcinoma	292 (60)
Pancreatic endocrine neoplasm	50 (10)
Malignant IPMN[a]	14 (3)
Solid-pseudopapillary carcinoma	8 (2)
Acinar cell carcinoma	6 (1)
Metastasis	5 (1)
Sarcoma	4 (1)
Malignant, other	2 (1)
Benign tumors	48 (10)
Serous cystadenoma	17 (3)
Benign, other	8 (2)
Pancreatitis	7 (2)
Retention cyst	7 (2)
Adenoma	5 (1)
Acinar cell cystadenoma	4 (1)
Unknown malignant potential	61 (12)
Benign IPMN[b]	47 (9)
Mucinous cystic neoplasm	14 (3)

IPMN intraductal papillary mucinous neoplasm

[a] Includes carcinoma in situ and invasive carcinoma

[b] Includes low- and moderate-grade dysplasia

Data Analysis

Descriptive and comparative statistics were performed using Statistical Software for the Social Sciences (SPSS) software, version 21 (IBM Corporation, Armonk, NY, USA). Continuous variables were compared using Student's t test or Mann–Whitney test, as appropriate by the type of distribution. Categorical variables were compared using χ^2 or Fisher's exact test depending on the number of observations. A p-value ≤ 0.05 was considered significant. Variables with a p-value ≤ 0.1 on univariate analysis were entered into a multivariate analysis (logistic regression), where the outcome variable was readmission. The multivariable model accounted for age, which is a known risk factor for readmission.[5,6] K-medoids clustering was performed to identify the major readmission groups by time interval (from discharge to readmission).

RESULTS

A total of 490 patients underwent pancreaticoduodenectomy (65 %), distal pancreatectomy (30 %), and central pancreatectomy (5 %). The indications for all operations

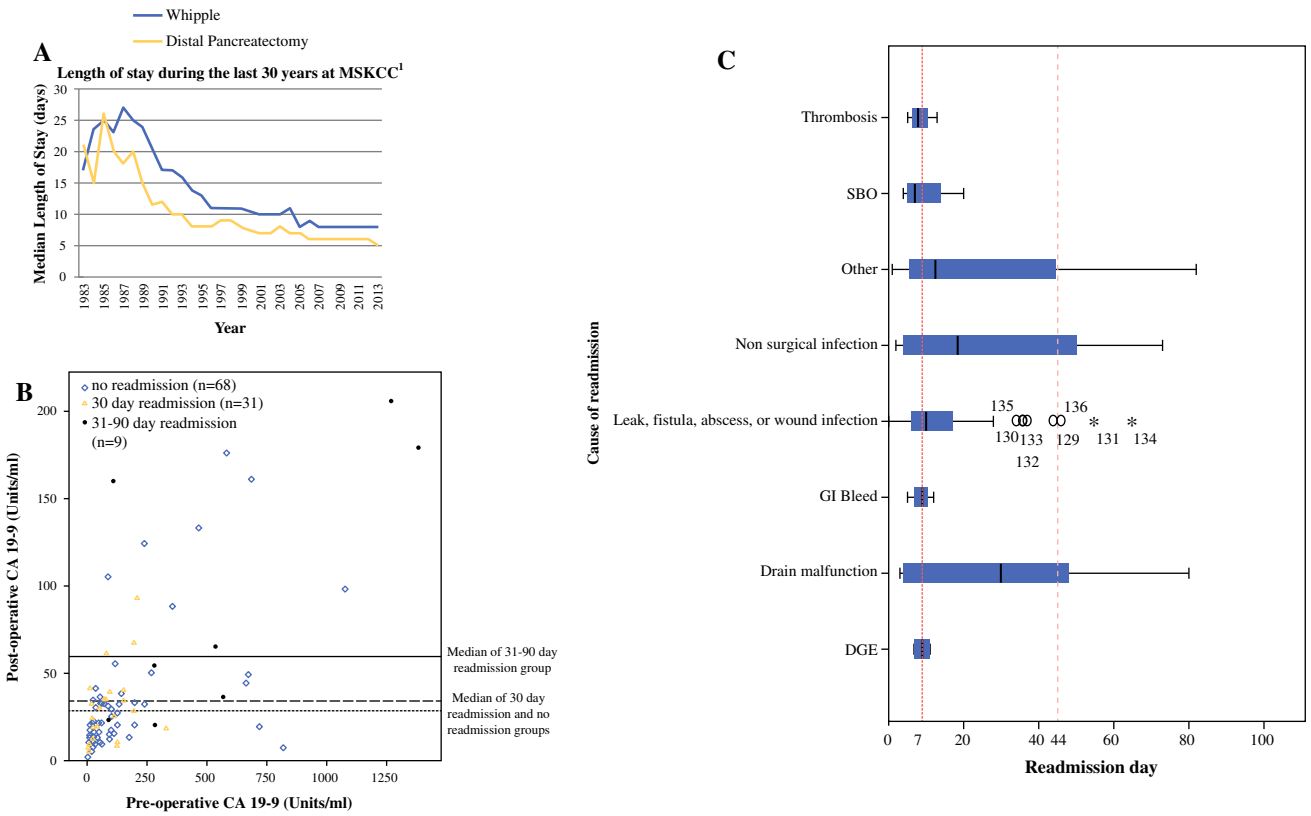

FIG. 1 **a** Drop of postoperative LOS from greater than 20 to 7 days in our institution during the last three decades. In the current study, the median postoperative LOS of the entire cohort was 7 days (range 3–73 days). (*1*) Whipple procedure, 2,849 patients; distal pancreatectomy, 1,037 patients. **b** *Scatter/dot* graph of preoperative and postoperative CA 19-9 levels by readmission groups. One patient had postoperative CA 19-9 of 6,500 (not shown in the graph). Graph calculated with patients who had both preoperative and postoperative CA 19-9. **c** *K*-medoids clustering and *box* plot of the causes of 90-day readmission by time. The two significant clusters were a group of 105 patients (74 % of all readmissions) who were readmitted after a median of 7 days after discharge, and a group of 27 patients (19 %) who were readmitted after a median of 44 days. This suggests that most readmissions happen early after discharge, but about one-fifth occur later. *Red lines* indicate *k*-medoids clustering analysis. The *vertical thick line* in the *middle* of each *box* indicates the median, whereas the *left* and *right borders* of the *box* mark the 75th and 25th percentiles, respectively. The *whiskers* lateral to the *box* extend to the most extreme point no longer than 1.5 times the interquartile range from the *box*. The *points* beyond the *whiskers* are outliers. *Thrombosis* deep vein thrombosis, pulmonary emboli, portal vein thrombosis, *other* non-specific intestinal and non-intestinal symptoms, adjuvant chemotherapy side effects, and non-related elective readmissions, *non-surgical infections* pneumonia, urinary tract infection, etc., *LOS* length of stay, *CA 19-9* carbohydrate antigen 19-9, *MSKCC* Memorial Sloan Kettering Cancer Center, *SBO* small bowel obstruction, *GI* gastrointestinal, *DGE* delayed gastric emptying

were tumors, which originated from the pancreas (85 %), ampulla (7 %), bile duct (4 %), and duodenum (2 %). Table 1 summarizes the pathological diagnosis and Fig. 1a summarizes the LOS. Median age was 65 years (range 19–91), and 48 % were female. During the index admission, 55 % (269 patients) experienced postoperative complications. Mortality rates within 30 and 90 days after surgery were 0.4 % (two patients) and 1 % (five patients), respectively. None of these deaths occurred during the index admission.

Demographic, operative, and perioperative data are summarized in Table 2, which compares the patients not readmitted with the patients who were readmitted, either within 30 days or only between 31 and 90 days after discharge. The independent predictors for 30-day readmission were mainly procedure related: discharge with a drain, central pancreatectomy, duct <3 mm, previous abdominal surgery, and longer LOS. The group readmitted between 31 and 90 days after discharge demonstrated a trend (p = non-significant) of higher proportions of cancer-related covariates [adenocarcinoma, positive margins, T3–T4 tumors, node-positive tumors, and higher preoperative carbohydrate antigen 19-9 (CA 19-9)] and significantly higher preoperative carcinoembryonic antigen (CEA; $p = 0.007$). To support this observation, we analyzed postoperative CA 19-9 and CEA by the different readmission groups (Table 3). A scatter/dot graph (Fig. 1b) demonstrates these differences. Comparison between patients who were readmitted within 90 days after discharge and patients who were not readmitted identified the

TABLE 2 Potential risk factors for readmission according to readmission group

Covariates	No readmission group ($n = 348$)	Group 1 (readmission within 30 days, $n = 113$)	Group 1 versus no readmission group[a]		Group 2 (readmission between 31 and 90 days, $n = 29$)	Group 2 versus no readmission group[b]	
			Univariate analysis (p-value)	Multivariate analysis (OR, CI, p-value)		Univariate analysis (p-value)	Multivariate analysis (OR, CI, p-value)
Age at operation (years, median, range)	67, 19–89	64, 19–90	0.2	NS	69.1, 44–91	0.15	1.06, 1.005–1.128, 0.03
Sex							
Male (%)	51	50	0.9	NA	62.1	0.3	NA
Female (%)	49	50			37.9		
BMI (m/kg^2)	27, 15–68	27, 18–45	0.6	NA	28, 20–39	0.6	NA
Preoperative albumin (g/dl)	4.2, 2.4–4.9 (347)	4.1, 0.1–5.1 (112)	0.105	NA	4, 3–4.5	0.2	NA
Bilirubin total (mg/dl, median, range)	0.6, 0.1–28.3 (344)	0.7, 0.2–17.5 (112)	0.5	NA	0.9, 0.3–15.3	0.7	NA
Preoperative CEA[c] (ng/ml, median, range)	3, 0.4–20.9 (143)	2.9, 0.7–11.2 (48)	0.3	NA	3.6, 2–18.5 (16)	0.007	1.14, 1.02–1.28, 0.02
Preoperative CA 19-9[c] (units/ml, median, range)	36, 0.5–14,920 (160)	44, 0.1–100,000 (57)	0.12	NA	100, 0.5–1,383 (18)	0.16	NA
ASA score (median, range)	3, 1–4 (121)	3, 1–4 (101)	1	NA	3, 2–4 (25)	1	NA
Operation duration (min, median, range)	218, 38–511 (347)	224, 98–462	0.3	NA	232, 89–388	0.4	NA
Estimated blood loss (cm^3, median, range)	300, 0–5,500 (343)	400, 0–2,500	0.8	NA	300, 100–1,400	0.7	NA
Length of stay (days, median, range)	7, 3–27	8, 4–73	<0.001	1.06, 1.01–1.1, 0.01	9, 6–34	0.006	NS
Comorbidities (%)							
Diabetes	21.6	25.7	0.4	NA	34.5	0.11	NA
Coronary artery disease	13.2	11.5	0.6	NA	13.8	1	NA
Atrial fibrillation	9.2 (347)	6.2	0.3	NA	17.2	0.2	NA
Pulmonary disease	11.8	11.5	0.9	NA	10.3	1	NA
CVA/TIA	3.4	6.2	0.2	NA	None	0.6	NA
Any comorbidity	88.5	86.7	0.6	NA	100	0.6	NA
Previous abdominal surgery	44.8	56.3 (112)	0.03	1.6, 1.03–2.6, 0.04	48.3	0.7	NA
Neoadjuvant chemotherapy[d]	9.3 (214)	19.4 (67)	0.03	NS	10 (20)	1	NA
Duct< 3 mm	41.9 (322)	55.5 (110)	0.01	1.6, 1.02–2.6, 0.04	26.9 (26)	0.13	NA
Soft gland	59.1 (320)	66.4 (110)	0.18	NA	50 (26)	0.4	NA
Stent placed preoperatively	29 (335)	29 (112)	0.9	NA	50 (26)	0.02	NS
Operative procedure (%)							
Whipple	62.9	68.1	0.3	NA	69	0.5	NA
Distal pancreatectomy	33.9	22.1	0.02	NS	20.7	0.15	NA
Central pancreatectomy	3.2	9.7	0.004	3.4, 1.3–9.2, 0.01	10.3	0.08	NS
Portal vein resection	5.1 (295)	4.2 (95)	0.7	NA	3.7 (27)	1	NA
Tumor origin (%)							
Ampulla	7.2	6.2	0.08	NS	3.4	0.09	NS
Bile duct	2.3	7.1			10.3		
Duodenum	3.4	5.3			3.4		
Pancreas	87.1	81.4			82.8		
Adenocarcinoma[e]	61.5	59.3	0.7	NA	69	0.4	NA

TABLE 2 continued

Covariates	No readmission group ($n = 348$)	Group 1 (readmission within 30 days, $n = 113$)	Group 1 versus no readmission group[a]		Group 2 (readmission between 31 and 90 days, $n = 29$)	Group 2 versus no readmission group[b]	
			Univariate analysis (p-value)	Multivariate analysis (OR, CI, p-value)		Univariate analysis (p-value)	Multivariate analysis (OR, CI, p-value)
Positive margin[d]	13.6 (213)	13.6 (66)	1	NA	20 (20)	0.4	NA
T3–T4[f] tumors[d]	85.5 (214)	79.1 (67)	0.2	NA	95 (20)	0.2	NA
Node positive tumors[d]	65 (214)	63 (67)	0.7	NA	75 (20)	0.4	NA
Discharge with drain	6.6	28.3	<0.001	3.3, 1.7–6.3, <0.001	20.7	0.006	NS
Discharge disposition (%)							
Home	75.6	58.4	0.002	NS	41.4	<0.001	NS
VNS	23	38.9			51.7		
Rehabilitation	1.4	2.7			6.9		
Postoperative complications (%)							
Complication G0–G2	86.2	67.3	<0.001	NS	72.4	0.04	NS
Complication G3–G4	13.8	32.7			27.6		
Any anastomotic leak	5.2	23	<0.001	NS	24.1	<0.001	NS
Pancreatic leak	4.3	18.6	<0.001	NS	20.7	<0.001	NS
Wound infection	6.6	13.3	0.02	NS	17.2	0.04	NS
Intra-abdominal abscess	4.9	13.3	0.002	NS	3.4	1	NA
Delayed gastric emptying	2.6	4.4	0.3	NA	3.4	0.6	NA
Paralytic ileus	3.2 (347)	7.1	0.07	NS	3.4	1	NA
Postoperative transfusions	25	34.5	0.05	NS	31	0.5	NA
Reoperation within the index admission	0.3 (346)	2.7 (112)	0.05	NS	3.4	0.15	NA

Preoperative laboratory blood work was recorded within 1 week prior to operation and postoperative CA 19-9 and CEA were recorded from 2 weeks until 6 months after surgery (for patients with adenocarcinoma)

OR odds ratio, *CI* confidence interval, *NS* non-significant, *NA* not analyzed, *BMI* body mass index, *CEA* carcinoembryonic antigen, *ASA* American Society of Anesthesiologists, *CVA* cerebrovascular accident, *TIA* transient ischemic attack, *VNS* Visiting Nurse Services, *CA 19-9* carbohydrate antigen 19-9, *AJCC* American Joint Committee on Cancer

[a] Comparison of the 30-day readmission group ($n = 113$) and the no readmission group ($n = 348$)

[b] Comparison of the 31–90-day readmission group and the no readmission group

[c] Labs were taken prior to surgery

[d] Calculated as the percentage of patients with adenocarcinoma as the primary or secondary diagnosis

[e] Adenocarcinoma as the primary or secondary diagnosis (301 patients): 30-day group (67 patients), 31–90-day group (20 patients), 90-day group (87 patients), and 214 were not readmitted

[f] Staging according to AJCC 7th edition

TABLE 3 Postoperative CA 19-9 and CEA analysis of patients with adenocarcinoma

	CA 19-9 postoperative (units/ml, *n*)	*p*-Value	CEA postoperative (ng/ml, *n*)	*p*-Value
31–90 days versus others[a]	59.5, 14–6,524 (12) versus 30, 1–4,481 (159)	0.04	2.4, 1.1–24.8 (10) versus 2.6, 0.9–738 (142)	0.8
31–90 days versus 30 days	59.5, 14–6,524 (12) versus 34, 5–1,887 (41)	0.1	2.4, 1.1–24.8 (10) versus 2.1, 1.1–61 (34)	0.3
31–90 days versus no readmission	59.5, 14–6,524 (12) versus 28.5, 1–4,481 (118)	0.03	2.4, 1.1–24.8 (10) versus 2.7, 0.9–738 (108)	0.8
30 days versus no readmission	34, 5–1,887 (41) versus 28.5, 1–4,481 (118)	0.7	2.1, 1.1–61 (34) versus 2.7, 0.9–738 (108)	0.2

The first CA 19-9 follow-up was performed at a median of 42 days after surgery (range 14–180). The first CEA follow-up was performed at a median of 44 days after surgery (range 14–180). Data are expressed as median and range. Adenocarcinoma as the primary or secondary diagnosis ($n = 301$ patients)

CA 19-9 carbohydrate antigen 19-9, *CEA* carcinoembryonic antigen

[a] Others include the no readmission group and the 30-day readmission group

TABLE 4 Leading causes for readmissions

	N (%)	Interval from discharge to readmission (days, median, range)	Length of stay during readmission (days)
Leading causes for 30-day readmissions ($n = 113$)			
Leak, fistula, abscess, or wound infection	65 (58)	9, 1–28	6.3 ± 7.7
Failure to thrive and other[a]	21 (19)	6, 1–29	4.8 ± 3.3
Non-surgical infections[b]	8 (7)	6, 2–24	6.1 ± 6.6
Drain malfunction	5 (4.5)	4, 3–30	9.2 ± 13.5
Gastrointestinal bleed	4 (3.5)	9, 5–12	4 ± 1.6
Small bowel obstruction	4 (3.5)	7, 6–20	4.5 ± 1.3
Thrombosis[c]	3 (2.5)	8, 5–13	8.7 ± 7.6
Delayed gastric emptying	2 (2)	9, 7–11	3.5 ± 0.7
Leading causes for 31–90-day readmissions ($n = 29$)			
Failure to thrive and chemotherapy-related symptoms[d]	11 (38)	55, 24–82	4.8 ± 4.4
Leak, fistula, abscess, or wound infection	8 (28)	40.5, 34–65	8.6 ± 13.1
Non-surgical infections[b]	6 (21)	55.5, 33–73	4.8 ± 3.9
Drain malfunction	4 (14)	60, 44–80	6.5 ± 3.3

[a] Non-specific intestinal and non-intestinal symptoms, elective readmission for other non-related cancer surgery or choledocholithiasis

[b] Pneumonia, urinary tract infection, etc.

[c] Deep vein thrombosis, pulmonary emboli, portal vein thrombosis

[d] Non-specific intestinal and non-intestinal symptoms and adjuvant chemotherapy side effects

following independent predictors of readmission (data not shown): discharge with a drain [odds ratio (OR) 3.5, confidence interval (CI) 1.9–6.5, $p < 0.001$], central pancreatectomy (OR 2.7, CI 1.1–6.5, $p = 0.03$), and postoperative LOS (OR 1.1, CI 1.01–1.1, $p = 0.006$).

The leading causes for readmission are summarized in Table 4. To further investigate the distribution pattern of the different causes for readmissions in the first 90 days after discharge, we constructed a box plot (Fig. 1c) showing that the majority of readmissions concentrate on the left side of the plot. To quantify this observation, *k*-medoids clustering was utilized to identify subsets where readmission times were clustered together (Fig. 1c).

Thirty-seven patients (7.5 %) presented to our emergency room [Urgent Care Center (UCC)] but were not readmitted. The most common cause for a UCC visit was failure to thrive (16 patients, 43 %), which occurred at a median of 31.5 days (range 2–88 days) after discharge,

followed by wound infection (15 patients, 41 %), which occurred at a median of 7 days (range 1–38 days) after discharge.

DISCUSSION

In recent years, public attention has focused increasingly on healthcare economics. Medicare has identified readmissions as a major contributor to healthcare expenditure, and estimated that 17.6 % of hospitalizations are associated with readmissions within 30 days, 76 % of which may be preventable. The estimated cost of the potentially preventable readmissions is $12 billion.[1] Obligatory reporting is already established for readmissions related to certain non-surgical conditions.[2] Based on this, several population-based studies explored preventable causes for readmissions after major surgical procedures. Tsai et al.[10] analyzed six major surgical procedures from 3,004 hospitals recorded in the Medicare database. In this study, the median readmission rate at 30 days was 13.1 %, and hospitals with high surgical volume and low surgical mortality had lower rates of surgical readmissions than other hospitals. The SEER-Medicare study by Hyder et al.[11] focused on patients who underwent pancreaticoduodenectomy. The incidence of 30-day readmission was 21.3 % and they concluded that the largest contributor to readmission was patient-related (i.e. preoperative comorbidities).

The 30-day readmission rate in our study (23 %) is in line with previous reports ranging from 16 to 50 %,[4,5,7,8,15–17] although the latter should be interpreted cautiously since different readmission timeframes were used—from 30 days to 1 year. Key factors that should be considered while evaluating readmission rates are LOS and mortality rates. It has been argued that pushing providers to lower readmission rates might bring about an increase in the hospital LOS in order to reduce early readmissions. At our institution, the LOS has decreased substantially in the last 30 years (Fig. 1a) to the current median of 7 days, which is among the shortest for high-volume hospitals in population-based studies[11] but comparable with hospital-based reports.[15] This difference can be explained by the different age groups included in each study design. A similar observation was demonstrated with 90-day mortality, which was 1 % in our study. Population-based mortality rates of high-volume hospitals are higher (8 %) but hospital-based rates are comparable.[11,15] Thus, it can be inferred from our results that both short LOS and low readmission rates can be accomplished despite the suggested inverse relationship.[9]

We analyzed readmissions in three different timeframes: within the first 30 days, within the first 90 days, and those occurring only between 31 and 90 days after discharge. These timeframes were based upon our assumption that pancreatic cancer, the major cause for pancreatic resections,[18] is known for its aggressive biology and can influence the readmission pattern. This relationship was demonstrated for 1-year readmissions after pancreatic resections but not as early as 90 days after discharge.[4,5] Most patients with adenocarcinoma receive postoperative chemotherapy,[19] which was a factor for readmission in the 31–90-day group but was absent in the 30-day readmission group (Table 4). Accordingly, Table 2 demonstrates that the independent risk factors for 30-day readmission are mainly procedure-related, and the factors for readmission between 31 and 90 days were non-procedure-related (preoperative CEA level and age). Several studies have identified age as a predictor for readmission.[5,9,10] We observed that the leading cause of late readmissions is failure to thrive (Table 4). Thus, future research should address the assumption that upon discharge from the index admission, older patients are prone to develop failure to thrive and are readmitted. This may provide a prevention strategy, i.e. failure to reach a predetermined nutritional index may justify nutritional intervention.

Preoperative CEA levels were shown to correlate with prognosis after curative pancreatic resection for cancer.[20–22] As such, our observation that higher preoperative CEA levels predict 31–90-day readmission supports the hypothesis that 31–90-day readmissions are influenced by the aggressive biology of pancreatic cancer. In addition, the proportion of most cancer-related covariates (adenocarcinoma, positive margin, T3–T4 tumors, node-positive tumors, and higher preoperative CA 19-9) are higher in the 31–90-day readmission group compared with the 30-day readmission group. While the trend is clear, no statistical significance was reached, possibly due to a lack of statistical power resulting from the small group of late readmissions. Additional support for this differential readmission pattern is derived from Table 4, which demonstrates that the majority of causes for readmissions in the 30-day group are procedure-related, while the majority in the 31–90-day group are not procedure-related.

We further analyzed postoperative CA 19-9 since persistently elevated CA 19-9 after pancreatic resection correlates with poor outcome and is likely related to persistent disease.[23] Postoperative CA 19-9 levels were twofold higher in the 31–90-day readmission group compared with the other groups. Taken altogether, to our knowledge this is the first report that presents the differential causality pattern of 30-day readmission and 31–90-day readmission groups. The implication is that it would be inappropriate to penalize providers that perform major surgeries on high-risk cancer patients, who are at substantial risk for readmission after the initial 30 days but within the 90-day penalty window.[24]

The goal is to lower the readmission rate by prevention. Most readmissions in our study were directly related to the natural course of pancreatic resections and were unavoidable (Table 4). Therefore, if it cannot be avoided then it may possibly be modified by earlier detection and treatment on an outpatient basis. Performing a short interval follow-up might identify patients who could be treated as outpatients, for indications such as drain malfunction, failure to thrive, delayed gastric emptying, non-surgical infection, and thrombosis. For that analysis, we utilized the *k*-medoids clustering to identify the major readmission groups (Fig. 1c). It appears that the majority of readmissions peak at a median of 7 days after discharge. Readmission prevention strategies should be developed, by which patients' follow-up takes place a few days earlier than the seventh day after discharge, and this follow-up should aim to identify early signs of the above causes for readmissions. It is important not to shift the follow-up date too soon before the seventh day since the early symptoms might not yet be apparent. On the other hand, shifting the follow-up date to the other side (in order to capture more patients) could result in patients being readmitted before follow-up. Such readmission prevention strategies are supported by our data from the UCC, in which 37 (7.5 % = 374/490) patients were prevented from readmission, a decrease of 7.5 % in the 90-day readmission rate that was mainly related to failure to thrive and wound infections.

As an observational analysis, this study has inherent limitations and the generalizability of results might be restricted, but it is this specific study setting that enables policymakers to analyze the causes of readmission at the patient level by excluding the hospital and surgeon effects. In addition, it is possible that we underestimated the readmission rates of patients who were readmitted to a secondary hospital. It is our premise that this underestimation, if it exists, is minimal since we record readmissions to secondary hospitals at our clinic visits and we instruct our patients to stay within the vicinity of the hospital in the first few weeks after operation. Usually patients who are readmitted to outside hospitals are transferred to our institution. An advantage of this study is its up-to-date large cohort in a high-volume referral center. Population-based studies are restricted to elderly patients, which limits their generalizability, while our study encompasses any adult patient. In addition, we used high-resolution readmission timeframes (30, 31–90, and 90 day), which enabled us to demonstrate the differential causality pattern of readmissions as early as within 90 days. Studies that do not use these timeframes could either analyze a heterogeneous 90-day group or analyze only the 30-day group, which is compared with the rest of the cohort, but in fact part (7.7 % in our study) of this later group is readmitted within 31–90 days. Of note, the statistical power of the 31–90-day readmission group multivariate model was limited by a small number of events. As well, confounding factors for the interpretation of CA 19-9 should be acknowledged: pancreatitis, biliary obstruction, hyperbilirubinemia, and cholangitis; however, these are not usually major confounders in the postoperative setting.[25]

CONCLUSIONS

Most readmissions after pancreatectomy are procedure-related in the first 30 days, but the 31–90-day period is more influenced by the natural history of the underlying diagnosis. The readmission penalty policy should account for the timing of readmission and the natural history of the underlying disease and procedure. Hospital and surgeon volumes are accepted predictors of readmission rate after pancreatic resection, and within this environment of high-volume hospitals and high-volume surgeons it is suggested from our study that most predictors and causes of readmissions are unavoidable but could be modifiable. Patients with increased risk for 30-day readmission (discharge with a drain, central pancreatectomy, duct <3 mm, previous abdominal surgery, and longer LOS) should be counseled upon discharge about their risk, and time-appropriate follow-up should be planned to minimize early readmissions, which peak at a median of 7 days after discharge.

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CONFLICT OF INTEREST Eran Sadot, Murray F. Brennan, Ser Yee Lee, Peter J. Allen, Mithat Gönen, Jeffery S. Groeger, T. Peter Kingham, Michael I. D'Angelica, Ronald P. DeMatteo, William R. Jarnagin, and Yuman Fong declare that they have no conflicts of interests regarding this study.

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