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ORIGINAL SCIENTIFIC REPORT

Fast-Track Pancreaticoduodenectomy: Factors Associated with Early Discharge

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Abstract

Background Pancreaticoduodenectomy is a complex surgery frequently associated with prolonged hospitalizations. However, there are a subset of patients discharged within 5 days from surgery; the preoperative and intraoperative characteristics of this subset are unknown.

Methods The NSQIP Targeted Pancreatectomy Dataset was used from 2014 to 2016. Patients who died within 30 days were excluded. A total of 10,741 patients undergoing pancreaticoduodenectomy were identified. Univariable and multivariable logistic regression analyses were performed for preoperative and intraoperative ACS-NSQIP variables to identify predictors of early discharge. Early discharge was defined as discharge 3–5 days after surgery.

Results A total of 1105 patients (10.3%) were discharged within 5 days following pancreaticoduodenectomy. On multivariable analysis, preoperative factors associated with early discharge included younger age (OR 0.988, $p < 0.001$), non-obesity (OR 0.737, $p = 0.001$), those receiving neoadjuvant chemotherapy (OR 1.424, $p < 0.001$), and lack of COPD (OR 0.489, $p = 0.005$) or hypertension (OR 0.805, $p = 0.007$). Intraoperative factors associated with early discharge on multivariable analysis were shorter operation duration (OR 0.999, $p = 0.002$), minimally invasive surgery (OR 3.537, $p < 0.001$), and hard pancreatic texture (OR 1.480, $p < 0.001$). Intraoperative factors associated with non-early discharge were epidural placement (OR 0.485, $p < 0.001$), drain placement (OR 0.308, $p < 0.001$), and jejunostomy tube placement (OR 0.278, $p < 0.001$). Patients discharged within 5 days had a 14.7% readmission rate compared to 17.0% for later discharges ($p = 0.047$).

Conclusions Multiple preoperative and intraoperative factors, including some that are potentially modifiable, were significantly associated with early discharge after pancreaticoduodenectomy. Patients with these characteristics may benefit from enhanced recovery after surgery programs and expedited disposition planning postoperatively.

Background

Pancreaticoduodenectomy (PD) is a complex surgical procedure with significant morbidity and mortality, oftentimes with lengthy hospital courses due to complex recovery and many potential complications [1–3]. Additionally, there is significant variation in length of stay (LOS) after PD. Identifying the factors that predict LOS following PD may support introduction of new clinical pathways approaches that can optimize patients' hospital

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course to reduce LOS. We can also predict risk factors for complications that we can manage proactively.

Within this context, there is currently significant pressure to control healthcare expenditures at the national level. Moreover, as Medicare shifts away from fee-for-service toward value-based bundled payments, administrators are challenged to improve cost and quality simultaneously. One key control lever at the hospital level is reducing LOS, a strategy that has proved both financially tenable and beneficial to patient outcomes [4, 5]. Reducing LOS on a systematic basis requires identification of patient factors that may favor early discharge and predictive clinical and social indicators that might suggest a patient is likely to have an unexpectedly long hospital course.

LOS for PD has gone down over time, but there is still room for improvement. In the 1970s, the median LOS was over 20 days, compared to 8–10 days at high-volume academic institutions presently [3, 6]. Opportunity for further reduction may come from new technical approaches including minimally invasive PD which includes laparoscopic [7] and robotic [8], which are increasingly performed and have been shown to reduce LOS. In addition, some factors such as age, comorbid illness, and low-volume centers have already been shown to be associated with prolonged hospital LOS after PD [9]. Strategies such as clinical care pathways and enhanced recovery after surgery programs for PD have demonstrated both reduced cost and hospitalization length [10, 11]. Early discharge after PD (within 5 days of surgery) has been shown to be safe and feasible in approximately 10% of patients in one recent series [12]. Understanding additional modifiable patient, facility, and surgery-related factors thus offers opportunity to optimize care.

Further elaboration of contributing patient demographics and factors may not only contribute to reduced LOS and healthcare costs, but also improvement in patient outcomes. Prolonged LOS not only adds to the economic costs [13], but also can delay adjuvant therapy initiation and put patients at risk of nosocomial infections and other avoidable complications [14]. While Medicare's initial implementation is focused on select high-volume conditions and surgeries, bundled payments will likely expand to include other major surgeries, such as PD [15]. In this study, our primary endpoint is to identify preoperative and intraoperative factors associated with early discharge after PD, defined as discharge by postoperative day 5 [12]. Our secondary endpoints are to assess the 30-day complication and readmission rates after early discharge.

Methods

National surgical quality improvement program

The American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) is a quality improvement database which contains both preoperative and postoperative data for a wide variety of surgical procedures [16]. Additionally, since 2014, NSQIP has maintained a pancreatectomy-specific database which includes several pancreatic surgery-specific variables. Pancreas-specific preoperative variables include preoperative obstructive jaundice, preoperative biliary stent, and chemotherapy or radiation therapy within 90 days of surgery. Intraoperative variables included pancreatic gland texture, pancreatic duct size, and vascular reconstruction. Postoperative variables include pancreatic fistula, postoperative percutaneous drainage, and delayed gastric emptying. The participant use date file (PUF) collected by NSQIP is de-identified and Health Insurance Portability and Accountability Act (HIPAA)-compliant. Institutional review board approval was obtained for this study which was determined to be exempt from patient consent requirement given the de-identified nature of the data.

Study population

The 2014–2016 NSQIP and Targeted Pancreatectomy PUF datasets were utilized. Patients who underwent PD for any indications were included for analysis, and Case ID variables were used to merge the NSQIP and Targeted Pancreatectomy datasets. PD was identified using CPT codes 48150, 48152, 48153, or 48154. A total of 10,971 patients were initially included. Patients who died during index hospitalization were excluded. Thus, 10,741 patients were available for final analysis. Patients discharged on postoperative day 5 or earlier were considered 'Early DC' [15].

Statistical analysis

Comparisons of the cohort discharged early with the cohort discharged after postoperative day 5 were performed utilizing Pearson's Chi-squared test for categorical variables and one-sided Student's t test or Mann–Whitney U test for continuous variables based on normality. Early and non-early discharge cohorts were compared utilizing univariable logistic regression. Variables significant on univariable regression were then compared with multivariable logistic regression. Only patients with all available significant variables from the univariable analysis were included in the multivariable analysis. Stepwise selection of variables using a bidirectional approach was sequentially

performed. All analyses were conducted in SPSS, version 24. A p value of less than 0.05 was considered statistically significant in final analyses.

Results

Between 2014 and 2016, 10,741 patients underwent PD with reported LOS postoperatively. The mean LOS postoperatively was 10.9 days, and median was 8 days (Fig. 1). A total of 1105 patients (10.3%) were discharged on postoperative day 5 or earlier (Early DC). Baseline patient demographics, preoperative comorbidities, and intraoperative factors are shown in Table 1. Univariable logistic regression for Early DC was performed for each preoperative and intraoperative variable.

All variables which reached statistical significance on univariable regression were placed into a multivariable regression model. Separate multivariable regression analyses were performed for preoperative variables alone and preoperative and intraoperative variables combined to identify predictors of Early DC. In total, 9699 patients (90.3%) had all available preoperative factors for analysis. Preoperative factors significantly associated with Early DC (Table 2) were younger age (OR 0.988, $p < 0.001$), non-obesity (OR 0.737, $p = 0.001$), receipt of neoadjuvant chemotherapy (OR 1.424, $p < 0.001$), and lack of COPD (OR 0.489, $p = 0.005$) or hypertension (OR 0.805, $p = 0.007$). Patients who received neoadjuvant chemotherapy were significantly more likely to have hard pancreatic texture (59.0 vs 38.8%, $p < 0.001$) and were less likely to develop a pancreatic fistula (10.1 vs 19.5%, $p < 0.001$) or delayed gastric emptying (13.4 vs 17.4%, $p < 0.001$). Smoking, preoperative transfusion, and preoperative creatinine and platelet levels were also significantly associated with non-early DC; however, these variables were no longer significant after controlling for intraoperative factors.

A total of 6131 patients (57.1%) had all available preoperative and intraoperative factors for analysis. Intraoperative factors significantly associated with Early DC on multivariable analysis included minimally invasive surgery (OR 3.537, $p < 0.001$, hard pancreatic texture (OR 1.480, $p < 0.001$) and shorter operative time (OR 0.999, $p = 0.002$). Epidural placement (OR 0.485, $p < 0.001$), and drain or jejunostomy tube placement (OR 0.308, $p < 0.001$; OR 0.278, $p < 0.001$, respectively) were significantly associated with non-early DC. Results of multivariable regression with both preoperative and intraoperative factors are shown in Table 3. To assess for possible influence of missing data on results, multiple imputation for missing variables was performed and both preoperative alone and preoperative and intraoperative combined analyses were similar.

Not unexpectedly, overall complications were lower in patients in the Early DC cohort. Overall infectious, bleeding, thrombotic, and pulmonary complications were significantly lower. Additionally, rates of pancreatic fistula (5.3 vs 19.4%, $p < 0.001$) and delayed gastric emptying

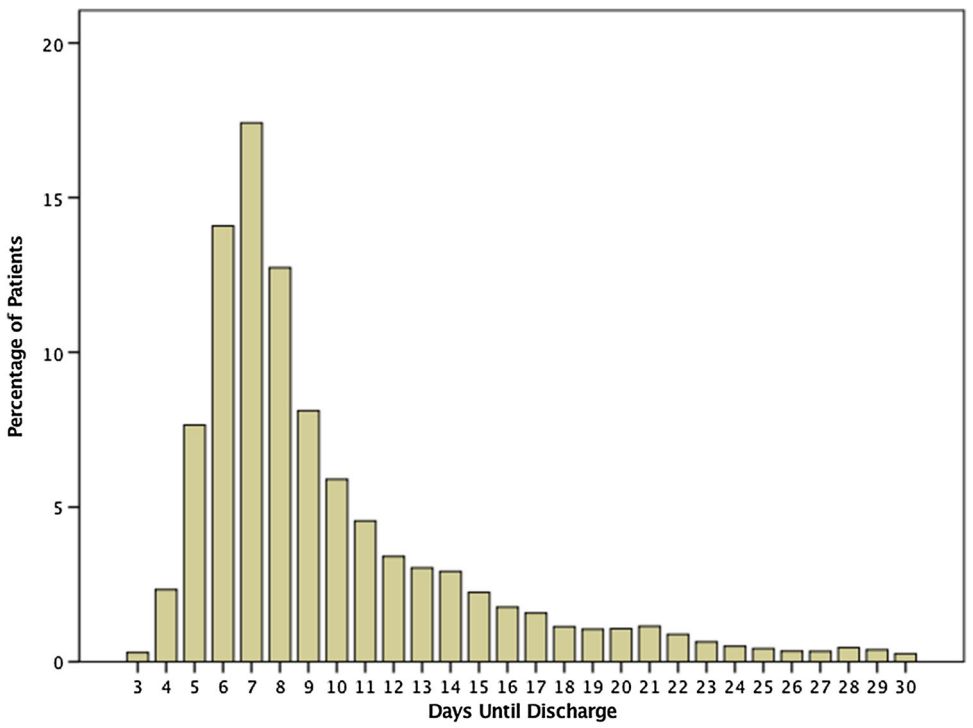

Fig. 1 Histogram of postoperative length of stay following pancreaticoduodenectomy

Table 1 Baseline characteristics comparing early versus non-early discharge

	Early discharge (n = 1105; 10.3%)	Non-early discharge (n = 9636; 89.7%)	p value
Gender	Male: 603 (54.6%)	Male: 5151 (53.5%)	0.482
Race			0.095
Caucasian	869 (85.4%)	7394 (84.9%)	
African-American	99 (9.7%)	751 (8.6%)	
Asian	30 (2.9%)	375 (4.3%)	
Hispanic	12 (1.2%)	153 (1.8%)	
Other	7 (0.7%)	41 (0.5%)	
Unknown	88	922	
Age (mean ± SD)	61.88 ± 11.517	64.63 ± 11.655	**<0.001**
Obesity	221 (20.2%)	2609 (27.2%)	**<0.001**
Transfer from outside facility	10 (0.9%)	293 (3.0%)	**<0.001**
Diabetes mellitus			0.084
None	851 (77.0%)	7183 (74.5%)	
Non-insulin dependent	116 (10.5%)	1232 (12.8%)	
Insulin dependent	138 (12.5%)	1221 (12.7%)	
Smoking	255 (23.1%)	1728 (17.9%)	**<0.001**
Dyspnea	36 (3.3%)	509 (5.3%)	**0.016**
Non-independent functional status	4 (0.4%)	83 (0.9%)	0.173
Preoperative sepsis			0.077
None	1101 (99.6%)	9526 (98.9%)	
SIRS	3 (0.3%)	74 (0.8%)	
Sepsis	1 (0.1%)	36 (0.4%)	
COPD	25 (2.3%)	431 (4.5%)	**0.001**
Ascites	2 (0.2%)	28 (0.3%)	0.517
Hypertension	473 (42.8%)	5179 (53.7%)	**<0.001**
Preoperative renal failure	0	6 (0.1%)	0.999
Dialysis	1 (0.1%)	25 (0.3%)	0.301
Disseminated cancer	34 (3.1%)	412 (4.3%)	0.06
Preoperative wound	0	55 (0.6%)	0.997
Steroid	30 (2.7%)	244 (2.5%)	0.715
Weight loss	183 (16.6%)	1562 (16.2%)	0.764
Bleeding disorder	23 (2.1%)	255 (2.6%)	0.264
Preoperative transfusion	2 (0.2%)	96 (1.0%)	**0.017**
Sodium	138.62 ± 3.245	138.81 ± 3.202	0.07
Creatinine	0.8228 ± .239	0.8839 ± .448	**<0.001**
Albumin	3.826 ± .560	3.745 ± .621	**<0.001**
Bilirubin	1.718 ± 2.534	1.694 ± 2.569	0.704
SGOT	55.2 ± 68.6	54.0 ± 70.7	0.996
Alkaline phosphatase	192.2 ± 174.4	185.6 ± 168.7	0.342
White blood cell count	7.41 ± 2.94	7.35 ± 2.66	0.980
Hematocrit	37.7 ± 4.9	37.7 ± 5.1	0.821
Platelet count	264 ± 99	258 ± 92	**0.023**
PTT	30.3 ± 5.3	30.0 ± 5.4	0.070
Emergent case	5 (0.5%)	44 (0.5%)	0.985
ASA class			**0.028**
1	6 (0.5%)	37 (0.4%)	
2	256 (23.2%)	2179 (22.6%)	
3	790 (71.6%)	6769 (70.3%)	

Table 1 continued

	Early discharge (n = 1105; 10.3%)	Non-early discharge (n = 9636; 89.7%)	p value
4	51 (4.6%)	642 (6.7%)	
5	1 (0.1%)	1 (0.0%)	
Preoperative jaundice	503 (45.7%)	4323 (45.2%)	0.755
Preoperative stent	589 (55.1%)	4824 (52.3%)	0.073
Neoadjuvant chemotherapy	235 (21.4%)	1570 (16.4%)	**<0.001**
Neoadjuvant radiation	86 (7.8%)	680 (7.1%)	0.37
Surgical indication			0.202
Ampullary carcinoma	62 (5.6%)	705 (7.4%)	
Cholangiocarcinoma	21 (1.9%)	251 (2.6%)	
Duodenal carcinoma	31 (2.8%)	272 (2.8%)	
Pancreatic adenocarcinoma	647 (58.6%)	5306 (55.1%)	
Neuroendocrine tumor	63 (5.7%)	644 (6.7%)	
IPMN	124 (11.2%)	1014 (10.5%)	
Mucinous cystic neoplasm	10 (0.9%)	129 (1.3%)	
Chronic pancreatitis	130 (11.8%)	926 (9.6%)	
Incision closure	1104 (99.9%)	9576 (99.4%)	0.421
Wound class 3 or 4	179 (16.2%)	1584 (16.4%)	**0.019**
Epidural	174 (15.7%)	2425 (25.2%)	**<0.001**
Operative time (min)	337.3 ± 113.9	374.0 ± 130.4	**<0.001**
Minimally invasive surgery	123 (11.5%)	413 (4.4%)	**<0.001**
Pancreatic texture			**<0.001**
Soft	327 (36.9%)	3428 (48.1%)	
Intermediate	107 (12.1%)	757 (10.6%)	
Hard	451 (51.0%)	2942 (41.3%)	
Pancreatic duct size			**0.002**
<3 mm	237 (26.0%)	2333 (31.4%)	
3–6 mm	496 (54.3%)	3850 (51.8%)	
>6 mm	180 (19.7%)	1252 (16.8%)	
Pancreaticojejunostomy	1002 (98.3%)	8753 (97.1%)	**0.03**
Drain placement	807 (73.2%)	8610 (89.6%)	**<0.001**
Vascular resection	131 (12.0%)	1703 (17.9%)	**<0.001**
Splenectomy	7 (0.6%)	49 (0.5%)	0.59
Diagnostic laparoscopy	88 (8.1%)	854 (9.0%)	0.307
Jejunostomy tube	15 (1.4%)	795 (8.4%)	**<0.001**
Liver ablation	3 (0.3%)	16 (0.2%)	0.436
Appendectomy	7 (0.6%)	48 (0.5%)	0.554
Liver biopsy	78 (7.2%)	792 (8.3%)	0.177
Colectomy	12 (1.1%)	164 (1.7%)	0.128
Lysis of adhesions	28 (2.6%)	488 (5.1%)	**<0.001**
Hepatectomy	7 (0.6%)	103 (1.1%)	0.416
Nephrectomy	2 (0.2%)	28 (0.3%)	0.516

Bold signifies a p value < 0.05

SD standard deviation, *SIRS* systemic inflammatory response syndrome, *COPD* chronic obstructive pulmonary disease, *SGOT* serum glutamic oxaloacetic transaminase, *PTT* partial thromboplastin time, *INR* international normalized ratio, *ASA* American Society of Anesthesiologists, *OR* operating room, *IPMN* intraductal papillary mucinous neoplasm

(4.0 vs 18.3%, $p < 0.001$) were also significantly less common in Early DC patients. Non-early DC was associated with higher reoperation rates (5.4 vs 1.2%, $p < 0.001$) and rehabilitation or skilled nursing facility discharge (13.6 vs 2.4%, $p < 0.001$). Overall complication rates are shown in Table 4.

Table 2 Multivariable analysis for early discharge based on preoperative factors alone

	Odds ratio	95% CI	*p* value
Preoperative variables			
Age	0.988	0.981–0.994	**<0.001**
Obesity	0.737	0.612–0.886	**0.001**
Transfer from outside facility	0.334	0.169–0.660	**0.002**
Smoking	1.275	1.064–1.528	**0.008**
Dyspnea	0.791	0.529–1.184	0.515
COPD	0.489	0.298–0.803	**0.005**
Hypertension	0.805	0.688–0.943	**0.007**
Preoperative transfusion	0.140	0.019–1.013	0.052
Creatinine	0.729	0.556–0.955	**0.022**
Albumin	1.127	0.989–1.283	0.072
Platelet count	1.001	1.000–1.002	**0.016**
ASA class	1.263	0.372–4.283	0.476
Neoadjuvant chemotherapy	1.424	1.187–1.710	**<0.001**

Bold signifies a p value < 0.05

COPD chronic obstructive pulmonary disease, *INR* international normalized ratio, *ASA* American Society of Anesthesiologists

Specifically looking at complications occurring after initial discharge, there was no significant increase in post-discharge complications in the Early DC group, with post-discharge pneumonia being significantly less likely (Table 5). Of note, timing of complication development was not available for pancreatectomy-specific complications. While causation cannot be determined, this implies that complications during the initial admission likely influenced initial LOS. However, importantly, patients with Early DC were not at an increased risk of complications after discharge, their overall complication rates were lower, and the overall 30-day readmission rate was significantly lower as well (14.7 vs 17.0%, $p = 0.047$). Readmission diagnoses are shown in Table 6. Early DC patients did have statistically significantly higher rates of readmission for obstruction and cholangitis, but the absolute numbers were small.

Discussion

This study reports the baseline demographic characteristics, patient comorbidities, and intraoperative factors associated with Early DC, or discharge after PD within 5 days of surgery, in the largest patient sample undergoing PD in a validated national cohort. We found that patients who were not obese, were younger in age, that received neoadjuvant chemotherapy, or without COPD and hypertension were more likely to have Early DC. Additionally, patients with hard pancreatic texture, shorter operative time, and minimally invasive surgery were also more likely to have Early DC, while patients receiving an epidural, an abdominal drain, a jejunostomy tube, or requiring lysis of adhesions were less likely to have Early DC. Surgical approach, drain placement, and jejunostomy tube insertion represent potentially modifiable factors. Furthermore, these preoperative and intraoperative factors can be used to predict who would be best eligible for early discharge after PD. The overall complication and readmission rates were significantly lower in the Early DC group.

The receipt of neoadjuvant chemotherapy is usually indicative of more advanced disease at presentation. However, patients able to undergo resection do not have an increase in surgical complications [17]. In fact, pancreatic fistula rates have been shown to be lower in patients undergoing neoadjuvant chemotherapy—reported at 6.9% in one meta-analysis [18]. In this study, the rates of pancreatic fistula and delayed gastric emptying were both significantly lower in patients who received neoadjuvant chemotherapy (both $p < 0.001$), possibly related to the concurrent increase in hard pancreatic texture. In one study of a single-institution cohort of 634 patients undergoing open PD, 9.6% of patients were discharged within 5 days of surgery. On multivariable analysis, these patients were more likely to have received neoadjuvant chemoradiation, an epidural for 3 days or less, and have no postoperative complications [12]. Importantly, patients discharged within 5 days were more likely to have started adjuvant chemotherapy within 8 weeks after surgery [12].

Postoperative complications were significantly associated with non-early DC in our patient cohort. Notably, there were three- to fivefold increases in rates of organ space infection, bleeding, pancreatic fistula, and delayed gastric emptying in patients with non-early DC. While this study was focused on preoperative and intraoperative risk factor identification, many of these factors were significantly associated with these subsequent complications on univariable analysis (i.e., bleeding disorder and open surgery with postoperative bleeding; neoadjuvant chemotherapy, drain placement, and pancreatic duct size and texture with both pancreatic fistula and delayed gastric emptying; and pancreatic texture and wound classification with organ space infection, all $p \leq 0.001$). Given the retrospective nature of the NSQIP database, one limitation is the inability to explore if the reported risk factors are the true drivers of later discharge or simply predictors of complication development; this is something that warrants future evaluation.

While this NSQIP cohort demonstrates that epidural placement during PD is associated with significantly longer LOS, other studies of epidural usage in abdominal surgeries have shown shortened LOS in addition to lower morbidity, mortality, and improved pain control [19, 20].

Table 3 Multivariable analysis for early discharge based on both preoperative and intraoperative factors

	Odds ratio	95% CI	*p* value
Preoperative variables			
Age	0.985	0.977–0.993	**<0.001**
Obesity	0.710	0.567–0.890	**0.003**
Transfer from outside facility	0.327	0.140–0.764	**0.010**
Smoking	1.221	0.977–1.526	0.079
Dyspnea	0.842	0.518–1.369	0.786
COPD	0.418	0.221–0.792	**0.008**
Hypertension	0.770	0.636–0.931	**0.007**
Preoperative transfusion	0.260	0.035–1.937	0.188
Creatinine	0.826	0.624–1.094	0.182
Albumin	1.052	0.893–1.239	0.544
Platelet count	1.000	1.000–1.001	0.369
ASA class	3.956	0.471–33.203	0.328
Neoadjuvant chemotherapy	1.335	1.064–1.675	**0.013**
Intraoperative variables			
Wound class	0.542	0.291–1.009	0.053
Epidural	0.485	0.369–0.636	**<0.001**
Operative time	0.999	0.998–1.000	**0.002**
Minimally invasive surgery	3.537	2.635–4.749	**<0.001**
Hard pancreatic texture	1.480	1.235–1.774	**<0.001**
Pancreatic duct size	0.938	0.751–1.171	0.654
Pancreatic reconstruction	0.419	0.319–1.608	0.419
Drain placement	0.308	0.250–0.380	**<0.001**
Vascular resection	0.642	0.477–0.865	**0.003**
Jejunostomy tube	0.278	0.141–0.548	**<0.001**
Lysis of adhesions	0.664	0.397–1.235	0.094

Bold signifies a p value < 0.05

COPD chronic obstructive pulmonary disease, *INR* international normalized ratio, *ASA* American Society of Anesthesiologists

Specifically, for pancreas surgery, an analysis of 12,440 patients undergoing pancreatectomy in the Nationwide Inpatient Sample showed that epidural placement was significantly associated with shorter LOS by 1.19 days, lower hospital charges by $16,814, and decreased mortality [21]. Jejunostomy tube placement has been shown to be associated with an increased LOS after PD, and its routine placement is no longer recommended after PD [22]. Similarly, the routine use of intraabdominal drains following PD has been shown to be associated with increased LOS and morbidity [23].

Implementation of various standardized clinical care pathways following PD has been applied at numerous institutions, though with different parameters at the various institutions. For example, a group from Toronto, Canada, showed implementation of a clinical pathway (including removal of nasogastric (NG) tube and Foley catheter by postoperative day 1, solid diet initiation by day 4, and discharge planning beginning by day 4) shortened their median LOS from 11 to 8 days ($p < 0.05$) despite similar rates of morbidity [24]. Finally, a group from Shanghai, China, implemented a pathway which included thoracic epidurals and initiation of enteral feeds via NG tube on day 1. Patients in their fast-track group had lower overall morbidity, less delayed gastric emptying, shorter LOS

Table 4 Overall complication rates between early and non-early discharges

Complication	Early discharge (n = 1105; 10.3%)	Non-early discharge (n = 9636; 89.7%)	*p* value
SSI	46 (4.2%)	847 (8.8%)	**<0.001**
DSSI	13 (1.2%)	177 (1.8%)	0.115
OSSI	52 (4.7%)	1495 (15.5%)	**<0.001**
Dehiscence	9 (0.8%)	136 (1.4%)	0.103
Pneumonia	5 (0.5%)	385 (4.0%)	**<0.001**
Reintubation	4 (0.4%)	306 (3.2%)	**<0.001**
Pulmonary embolus	1 (0.1%)	124 (1.3%)	**<0.001**
Failure to wean ventilator	1 (0.1%)	262 (2.7%)	**<0.001**
Renal insufficiency	1 (0.1%)	72 (0.7%)	**0.012**
Renal failure	1 (0.1%)	61 (0.6%)	**0.024**
UTI	10 (0.9%)	316 (3.3%)	**<0.001**
CVA	0 (0%)	25 (0.3%)	0.09
Cardiac arrest	1 (0.1%)	29 (0.3%)	0.209
MI	5 (0.5%)	93 (1.0%)	0.09
Bleeding	77 (7.0%)	1947 (20.2%)	**<0.001**
DVT	11 (1.0%)	270 (2.8%)	**<0.001**
Sepsis	40 (3.6%)	948 (9.8%)	**<0.001**
Septic shock	3 (0.3%)	259 (2.7%)	**<0.001**
Clostridium difficile infection	6 (0.9%)	122 (2.4%)	0.16
Pancreatic fistula	58 (5.3%)	1851 (19.4%)	**<0.001**
Delayed gastric emptying	44 (4.0%)	1730 (18.3%)	**<0.001**
Postoperative percutaneous drain	58 (5.3%)	1311 (13.8%)	**<0.001**
Reoperation	13 (1.2%)	521 (5.4%)	**<0.001**
Non-home discharge destination	26 (2.4%)	1305 (13.6%)	**<0.001**

Bold signifies a p value < 0.05

SSI superficial surgical site infection, *DSSI* deep surgical site infection, *OSSI* organ space surgical infection, *UTI* urinary tract infection, *CVA* cerebral vascular accident, *MI* myocardial infarction, *DVT* deep venous thrombosis

Table 5 Complication rates occurring after initial hospital discharge between early and non-early discharges

Complication	Early discharge (n = 1105; 10.3%)	Non-early discharge (n = 9636; 89.7%)	p value
SSI	41 (3.7%)	297 (3.1%)	0.274
DSSI	12 (1.1%)	80 (0.8%)	0.387
OSSI	52 (4.7%)	508 (5.3%)	0.472
Dehiscence	9 (0.8%)	53 (0.6%)	0.290
Pneumonia	1 (0.1%)	60 (0.6%)	**0.019**
Reintubation	3 (0.3%)	38 (0.4%)	0.795
Pulmonary embolus	1 (0.1%)	39 (0.4%)	0.120
Failure to wean ventilator	1 (0.1%)	25 (0.3%)	0.512
Renal insufficiency	1 (0.1%)	21 (0.2%)	0.721
Renal failure	0 (0%)	10 (0.1%)	0.613
UTI	7 (0.7%)	69 (0.7%)	1.000
CVA	0 (0%)	6 (0.1%)	1.000
Cardiac arrest	1 (0.1%)	0 (0%)	0.103
MI	3 (0.3%)	10 (0.1%)	0.142
Bleeding	0 (0%)	4 (0%)	1.000
DVT	11 (1.0%)	83 (0.9%)	0.609
Sepsis	29 (2.6%)	233 (2.4%)	0.689
Septic shock	3 (0.3%)	51 (0.5%)	0.366

Bold signifies a p value < 0.05

SSI superficial surgical site infection, *DSSI* deep surgical site infection, *OSSI* organ space surgical infection, *UTI* urinary tract infection, *CVA* cerebral vascular accident, *MI* myocardial infarction, *DVT* deep venous thrombosis

(13.94 vs 17.6 days, $p < 0.0001$) and a 15% overall cost reduction ($p < 0.001$) [25].

Standardized enhanced recovery after surgery (ERAS) guidelines have been developed for PD in an attempt to decrease complications and LOS and provide a more broadly applicable framework than individualized fast-track programs [26]. ERAS represents a multimodal, multidisciplinary approach which involves the surgeon, anesthesiologist, nursing staff, and unit staff taking care of the patient postoperatively. Specific to PD, current guidelines recommend against routine NG tube placement and somatostatin use, advocate for maintaining near-zero fluid balance perioperatively, preoperative carbohydrate loading, initiation of oral diet by day 3, and early drain removal if no evidence of pancreatic fistula [26]. A systematic review and meta-analysis of the PD ERAS protocol showed reduced LOS between 2 and 6 days with an absolute decrease in overall complication risk of 8.2% ($p = 0.008$) [10].

Table 6 Readmission rates and diagnoses between early and non-early discharges

Readmission	Early discharge (n = 1105; 10.3%)	Non-early discharge (n = 9636; 89.7%)	p value
Any readmission	162 (14.7%)	1639 (17.0%)	**0.047**
Any infectious	58 (5.2%)	618 (6.4%)	0.132
SSI	3 (0.3%)	61 (0.6%)	0.139
DSSI	6 (0.5%)	50 (0.5%)	0.916
OSSI	31 (2.8%)	350 (3.6%)	0.159
Wound disruption	6 (0.5%)	22 (0.2%)	0.052
DVT/PE	1 (0.1%)	36 (0.4%)	0.128
Pulmonary	3 (0.3%)	62 (0.6%)	0.132
Renal	0 (0%)	13 (0.1%)	0.222
UTI	1 (0.1%)	14 (0.1%)	0.644
Clostridium difficile	1 (0.1%)	11 (0.1%)	0.824
CVA	1 (0.1%)	2 (0%)	0.189
Anemia	0 (0%)	29 (0.3%)	0.068
Sepsis	12 (1.1%)	109 (1.1%)	0.893
Ileus	5 (0.5%)	23 (0.2%)	0.187
Fistula	0 (0%)	6 (0.1%)	0.407
Obstruction	4 (0.4%)	11 (0.1%)	**0.037**
Constipation	2 (0.2%)	7 (0.1%)	0.238
Abscess	1 (0.1%)	19 (0.2%)	0.436
Cholangitis	3 (0.3%)	4 (0%)	**0.005**
GI Bleed	4 (0.4%)	24 (0.2%)	0.486
Fever	3 (0.3%)	19 (0.2%)	0.605
Diarrhea	0 (0%)	5 (0.1%)	0.449
Abdominal pain	10 (0.9%)	54 (0.6%)	0.159
Ascites	0 (0%)	18 (0.2%)	0.15
Failure to thrive	6 (0.5%)	34 (0.4%)	0.326
Nausea/ vomiting	11 (1.0%)	74 (0.8%)	0.419
Dehydration	5 (0.5%)	72 (0.7%)	0.271
Aneurysm	2 (0.2%)	6 (0.1%)	0.171
Gastrojejunal ulcer	0 (0%)	9 (0.1%)	0.309
Gastroparesis	1 (0.1%)	20 (0.2%)	0.404
Dyspepsia	3 (0.3%)	44 (0.5%)	0.377
Pyloric stenosis	2 (0.2%)	12 (0.1%)	0.622

Bold signifies a p value < 0.05

SSI superficial surgical site infection, *DSSI* deep surgical site infection, *OSSI* organ space surgical infection, *DVT/PE* deep venous thrombosis/pulmonary embolus, *UTI* urinary tract infection, *CVA* cerebral vascular accident

The current fee-for-service reimbursement model is untenable, and there is a push to adopt bundled payments in many different clinical settings, including surgical admissions [27, 28]. High-volume surgeons and hospitals have shown significantly lower mortality rates (OR 0.32, $p < 0.001$), a 5-day shorter length of stay ($p < 0.001$), and significantly lower costs ($12,275 USD, $p < 0.001$) [29] and a reduced risk of prolonged (greater than 14 days) length of stay as well [9]. As reimbursement shifts toward value-based, bundled payments, the implementation of enhanced recovery pathways has the potential to decrease healthcare costs [30]. Importantly, in a study of Medicare beneficiaries undergoing coronary artery bypass grafting, colectomy, or total hip replacement, bundled payments were shown to be associated with decreased LOS and overall inpatient cost without concomitant increases in post-discharge care spending or readmissions [31]. While early implementation of bundled payments in surgery has focused on high-volume, common procedures, its scope will likely increase to more complex surgeries, and an early understanding of costs and disposition planning will be imperative. Implementation of clinical pathways following PD has been shown to decrease overall costs by 23–39% [32, 33].

Limitations of this study include its retrospective design. Additionally, we were unable to control for whether patients were in an ERAS or fast-track perioperative care protocol. We recommend the next generation of surgical databases which include information on perioperative care protocols, given their important contribution to postoperative outcomes. We were also unable to assess hospital or surgeon volume, both of which are known to impact pancreaticoduodenectomy outcomes [34].

Pancreaticoduodenectomy remains a complex surgical procedure with significant morbidity. However, significant strides in the perioperative care of these patients have resulted in improved outcomes as well as shortened hospital LOS. Identification of patients who can safely and effectively undergo PD with discharge from the hospital within 5 days of surgery can further improve outcomes both for the individual patient and for the overall healthcare system.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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