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Multivariable analysis of predictors of unplanned hospital readmission after pancreaticoduodenectomy: development of a validated risk score

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Abstract

Background: Unplanned hospital readmission after pancreaticoduodenectomy (PD) is usually due to surgical complications and has significant clinical and economic impact. This study developed a risk score to predict 30-day readmission after PD.

Methods: Patients undergoing PD between 2009 and 2016 were reviewed from a prospective database. Predictors of readmission were identified using a multivariable logistic regression model, from which a points-based risk scoring system was derived.

Results: 81 of 518 patients (15.6%) were readmitted within 30 days. History of cardiac disease ([odds ratio] OR = 2.12; 95% CI: 1.12–4.56), CRP>140 mg/L on post-operative day 3 (OR = 2.34; 95% CI: 1.37–4.35) and comprehensive complication index >14 (OR = 1.74; 95% CI: 1.03–2.85) were independent predictors of readmission. The regression coefficients were used to generate a risk score with excellent calibration ($p = 0.917$) and good discrimination (c-index = 0.65; 95% CI: 0.58–0.71; $p < 0.001$). Patients were categorised as low, moderate and high risk, with readmission rates of 6.4%, 13.4% and 23.0% respectively ($p < 0.001$).

Conclusion: The risk score identifies patients at high risk of readmission after pancreaticoduodenectomy. Such patients may benefit from pre-discharge imaging and/or enhanced follow-up, which may potentially reduce the impact of readmissions.

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Introduction

Pancreaticoduodenectomy (PD) is a complex surgical procedure for the treatment of malignant or pre-malignant lesions in the periampullary region.[1] Even in specialist centres, PD is associated with a significant risk of post-operative morbidity, around 20–60%.[2–4] Despite these figures, in contemporary series the average duration of hospital stay after PD has reduced to 7–9 days,[5] which is mainly due to a combination of centralization and increased use of enhanced recovery after surgery (ERAS) pathways.[6] Emergency hospital readmission after elective surgery, including after PD, is a major problem for healthcare organisations worldwide, and carries a significant financial burden.[7] Hospital readmission has been reported as an important measure of health care quality,[7,8] and is considered to be a 'failed discharge' by the U.K. National Health Service (NHS).[9] In the majority of patients, readmission after major surgery is precipitated by a post-operative complication, which was either undiagnosed or under-treated during the index admission.[10] Post-operative pancreatic fistula (POPF), delayed gastric emptying (DGE) and surgical site infections (SSI) are important determinants of morbidity and

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readmission after PD.[11,12] Identification of patients at risk of readmission after PD has several potential advantages. For example, high risk patients may benefit from imaging prior to hospital discharge and/or early outpatient and/or telephone follow-up consultation. A scoring system to predict readmission after pancreatectomy has been derived from the multi-institutional NSQIP database of over 2000 patients.[13] However, this study included all types of pancreatectomy (PD, distal and central), and has not been validated specifically for PD. The aim of this study was to develop a risk score to predict 30-day hospital readmission after PD in a single high volume U.K. centre.

Methods

Study design

Data were retrospectively collected from a prospectively maintained database of patients who underwent PD in a single high volume centre during an eight-year period (2009–2016). Patients who died during the index admission were excluded from analysis. Data collection included pre-operative demographic data (sex, age, smoking history, body mass index [BMI] – kg/m^2), comorbidities, radiological assessment (diameter of the pancreatic duct on computerized tomography), pre-operative biliary drainage, pre-operative validated risk score for POPF,[12] intra-operative data [vascular resection and/or additional procedures], histopathology, post-operative complications [POPF – international study group (ISGPF) grade B/C fistula,[14] DGE, abdominal collection, SSI, chest infection, cardiac failure, deep venous thrombosis, renal failure, stroke, arterial pseudoaneurysm, gastrointestinal bleeding], post-operative laboratory data [C-reactive protein (CRP) (mg/L) on day 3 and before discharge; white blood cells count (g/L) on day 1, 3 and before discharge; total bilirubin (mg/L) on day 1, 3 and before discharge; drain fluid amylase (UI) on day 3] and clinical follow-up up to date of death or latest outpatient visit. Surgical complications were standardized for the purposes of statistical analysis according to the comprehensive complication index (CCI)[15] and Clavien-Dindo classification.[16]

Hospital readmission

Hospital readmission was defined as readmission to any hospital within 30 days after discharge from the index admission. The management of patients who were readmitted to local non-specialist hospitals was dictated by their clinical condition and guided by telephone advice provided by the specialist centre. Readmitted patients with severe complications necessitating specialist input and/or intervention were urgently transferred to the specialist centre. The reason for readmission was recorded retrospectively after evaluation of clinical, laboratory and radiological data that were obtained during the readmission episode.

Statistical analysis

Continuous variables were presented as median with interquartile range (IQR) and categorical variables as the absolute number of cases (n) and a percentage. The analysis was based on the binary endpoint of hospital readmission within 30 days of discharge. Comparisons between groups were performed using Fisher's exact test for categorical variables and Mann–Whitney *U* test for continuous variables.

Development of the risk score

Univariable analysis with binary logistic regression was performed to identify predictors associated with hospital readmission. All factors from the univariable analysis with $p < 0.20$ were included in a multivariable binary logistic regression model, with a backwards stepwise approach used to select significant independent predictors for inclusion in the risk score. Prior to the analysis, continuous variables were dichotomised to simplify the resulting score. Initially, a receiving operating characteristic (ROC) curve analysis was used in an attempt to identify optimal cut-off values for dichotomisation. However, this did not find any cut-offs that were clearly superior, hence the median values were used.

A risk score was produced based on the β coefficients (log-odds) from the resulting model. These coefficients were rounded to the nearest integer, after being multiplied by ten, to minimise the impact of rounding errors. These values were then used as multipliers in the risk score formula.

The performance of the risk score was assessed. The Hosmer–Lemeshow test was used as a goodness-of-fit test for the risk score calibration, to verify the agreement between predicted and observed results. Internal validation of the discrimination of the model was performed using the concordance statistic index (c-index), using a bootstrapping-based resampling method, as described by Harrell *et al.*[17] In summary, 1000 bootstrap samples were generated from the entire cohort, and the model was fitted to each one. The c-index was calculated for each sample and, in each case, the difference between the resulting c-index and the c-index for the whole cohort was generated. The average of these differences was calculated, to give an estimate of the degree of optimism. This value was subtracted from the c-index for the cohort as a whole, to give an optimism-corrected c-index.

Survival analysis

Initially, the association between 30-day readmission and patient survival was assessed using a Kaplan–Meier curve, with comparisons between groups performed using a log-rank test. A multivariable analysis was performed, using a Cox regression model, to test whether hospital readmission was an independent predictor of patient survival. Factors with a $p < 0.20$ in the univariable analysis of survival were considered for inclusion, with a backwards stepwise approach used to select factors for the final model. Collinearity between explanatory survival variables

was tested using Cramer's V test and Spearman's correlation coefficients, and highly correlated variables were excluded from the analysis to prevent issues with multicollinearity.

Statistical analysis tests were performed using SPSS version 24 software (SPSS Inc., Chicago, IL, USA) and SAS/STATA version 9.4 software (Copyright © 2013 SAS Institute Inc., Cary, NC, USA). A p value less than 0.05 was considered statistically significant throughout.

Results

During the study period, 542 consecutive patients underwent PD. Of these, 24 patients (4.4%) died during the index admission and were excluded from further analysis, leaving 518 patients. Data were available for all variables in 99.5% of cases, with the maximum number of patients with missing data being three for the post-operative CRP. A total of 81 of 518 patients (15.6%) had an unplanned hospital readmission within 30 days of discharge, of whom 53 patients (65%) were readmitted to local non-specialist hospitals. Readmission occurred a median of 13 days (IQR 4–20) after discharge, with 33 (41%) of readmissions occurring within 7 days of discharge. The median length of hospitalization during the readmission episode was 6 days (IQR 2–15). Unplanned hospital readmission between 30 and 90 days after discharge occurred in seven patients (1.4%), and none were related to postoperative complications.

Surgical complications were the most common reason for readmission (Table 1). Overall, 25 readmitted patients had complications relating to a post-operative pancreatic fistula. In 72 patients (89%) complications resulting in readmission were not diagnosed during the index admission, including 8 patients with a POPF. Of six patients readmitted with superficial SSI, three patients had an abdominal CT that excluded deep collections, four needed surgical debridement of the wound plus antibiotic therapy and two received antibiotics only. For these patients the median length of hospitalisation was 2 days (IQR: 1–4).

Table 1 Reason for 30-day readmission after the discharge from the index pancreaticoduodenectomy

Reason for readmission	Number of Patients (%)
Intra-abdominal collection	
POPF related	14 (17.3%)
Non-POPF related	9 (11.1%)
Delayed gastric emptying	
POPF related	8 (9.9%)
Non-POPF related	14 (17.3%)
Haemorrhage	
POPF related	3 (3.7%)
Non-POPF related	6 (7.4%)
Surgical site infection (superficial)	6 (7.4%)
Chest infection	5 (6.2%)
Diarrhoea	4 (4.9%)
Other	12 (14.8%)
Total	81 (100%)

Abbreviations: POPF: Post-operative pancreatic fistula.

The severity of complication during readmission was classified as mild-moderate (Clavien-Dindo class I-IIIa) in 67 patients (83%) and severe (class IIIb or above) in 14 patients (17%), including 7 patients who subsequently died. A total of 50 readmitted patients (62%) had a higher Clavien-Dindo grade of complication than was evident during the index admission, including 13 patients (16%) readmitted with severe complications. Of 53 patients who were readmitted to local non-specialist hospitals, 16 patients (30%) required emergency transfer to the index hospital for further management and 10 patients (19%) had severe complications, including 3 patients (6%) who died.

Overall, 53 readmitted patients were treated by pharmacological therapy and 28 patients underwent interventions (radiological drainage 16, surgery 5, endoscopic therapy 2, angioembolization 5). Of 25 patients with complications related to POPF, 11 required either radiological (N = 9) or surgical (N = 2) intervention.

There was no significant difference in patient age, sex or BMI between patients who were readmitted within 30 days, and those that were not (Table 2). There was a significantly increased incidence of cardiac disease in readmitted patients. Of 12 readmitted patients with pre-existing cardiac disease, the majority (92%) had either ischaemic heart disease (N = 6) or chronic atrial fibrillation (N = 5), and one patient had valvular heart disease.

Pancreatic duct width was significantly smaller in readmitted patients. The incidence of hospital readmission after PD has not changed significantly since implementation of an ERAS (Enhanced Recovery After Surgery) pathway in December 2012. Patients with post-operative morbidity during index admission were significantly more likely to be readmitted (20% vs. 12%, p = 0.012). The incidence of severe (grade III or more) complications and CCI score during the index admission were both significantly higher in patients that were subsequently readmitted (Table 3). The presence of superficial SSI during index admission was significantly more likely in readmitted patients, whilst there was no significant difference in the incidence of POPF (diagnosed during the index admission) between groups. Of the post-operative laboratory variables considered, CRP and WBC measured on the third post-operative day were significant higher in readmitted patients (Table 3).

Risk factors for hospital readmission

After multivariable analysis, three independent predictors of 30-day readmission were identified, namely a history of cardiac disease, CRP ≥140 mg/L on the third postoperative day and CCI >14 (Table 4). The regression model was then converted into a risk score, based on the β-coefficients. Patients with a history of

Table 2 Distribution and comparison of peri-operative variables between groups and the entire cohort

Variable	All Patients (n = 518)	Missing Data (n)	No readmission (n = 437)	30-days readmission (n = 81)	p-value
Age (year)	67.7 (60.5–73.5)	0	68.0 (60.8–73.4)	67.0 (56.8–74.1)	0.416
Male sex	276 (53.3%)	0	234 (53.5%)	42 (51.9%)	0.780
Body mass index (kg/m^2)	25 (22–28)	0	25 (22–28)	25 (22–29)	0.741
Smoking status		0			0.465
Non-smoker	335 (64.7%)		281 (64.3%)	54 (66.7%)	
Active smoker	69 (13.3%)		56 (12.8%)	13 (16.0%)	
Ex-smoker	114 (22.0%)		100 (22.9%)	14 (17.3%)	
Past medical history		0			
Asthma	26 (5.0%)		23 (5.3%)	3 (3.7%)	0.780
Cardiac disease	44 (8.5%)		32 (7.3%)	12 (14.8%)	**0.031**
COPD	28 (5.4%)		23 (5.3%)	5 (6.2%)	0.795
Hypertension	192 (37.1%)		161 (36.8%)	31 (38.3%)	0.811
Diabetes Mellitus type 2	90 (17.4%)		15 (18.5%)	75 (17.2%)	0.773
Chronic renal failure	9 (1.7%)		8 (1.8%)	1 (1.2%)	1.000
Myocardial infarction	13 (2.4%)		11 (2.4%)	2 (2.5%)	0.965
Birmingham POPF risk score	0.26 (0.13–0.39)	0	0.25 (0.13–0.38)	0.31 (0.15–0.42)	0.082
Pre-operatory biliary stent	320 (61.8%)	0	273 (62.5%)	47 (58.0%)	0.443
Pancreatic duct width CT (mm)	3.7 (1.0–6.1)	0	4.0 (1.0–6.1)	2.9 (1.0–6.0)	**0.050**
Type of procedure		0			0.999
Pylorus preserving	473 (91.3%)		399 (91.3%)	74 (91.4%)	
Classic Whipple	45 (8.7%)		38 (8.7%)	7 (8.6%)	
Venous and or arterial resection	79 (15.3%)	0	65 (14.9%)	14 (17.3%)	0.582
Additional procedure	23 (4.4%)	0	19 (4.3%)	4 (4.9%)	0.770
ERAS protocol applied[a]	252 (48.6%)	0	209 (82.9%)	43 (17.0%)	0.451

Data are reported as N (%), with p-values from Fisher's exact tests, or as median (IQR), with p-values from Mann–Whitney tests, as applicable. Bold p-values are significant at $p < 0.05$.
Abbreviations: COPD: Chronic obstructive pulmonary disease; ERAS: enhanced recover after surgery; CT: computed tomography; POPF: postoperative pancreatic fistula.
[a] Started on December 2012.

cardiac disease scored 8 points, those with CRP ≥140 mg/L on the third post-operative day scored 8 points, and those with CCI >14 scored 5 points. To calculate a score for a patient, these three components are simply added together, with a value of 0 used where the patient does not fit the stated criteria. This gives a score with a potential range from 0 to 21.

The score was found to have excellent calibration as assessed by the Hosmer–Lemeshow test ($p = 0.917$). It was also found to have good discrimination, with an optimism-corrected c-index of 0.65 (95% CI: 0.58–0.71; $p < 0.001$). Readmission rates within 30 days were found to increase greater than five-fold across the range of the score, from 6.4% in those scoring 0 points, to 35.3% in those scoring 21 points. This relationship is shown graphically in Fig. 1.

The score was used to stratify patients into three groups, namely low (0 points), moderate (5 and 8 points) and high risk (13, 16 and 21 points) for readmission. The observed 30 day readmission rates these groups were 6.4%, 13.4% and 23.0%, respectively ($p < 0.001$) (Fig. 1).

Of 81 readmitted patients, 14 (17%) had a CT scan within 4 days prior to hospital discharge. Nine patients had a positive finding (fluid collection) on pre-discharge CT, were treated conservatively, and all fulfilled discharge criteria.

Survival analysis

The median survival of the entire cohort was 34.1 months (95% CI: 28.1–40.0). Patients readmitted within 30 days had significantly shorter overall survival [25.3 months (95% CI: 19.4–31.3) vs. 39.1 months (95% CI: 32.7–45.5); $p = 0.002$] (Fig. 2). There was no significant difference in histological subtype of tumours between patients who were readmitted or not ($p = 0.131$). All factors from Tables 2 and 3 with $p < 0.2$ on univariable Cox regression analysis were considered for inclusion in a backwards stepwise multivariable model. Male sex, BMI, history of asthma or chronic kidney disease, intra-operative vascular reconstruction, POPF and post-operative cardiac complications were excluded by the stepwise procedure. Multivariable analysis

Table 3 Distribution and comparison of postoperative factors between groups and the entire study cohort

Variable	All patients (n = 518)	Missing Data (n)	No readmission (n = 437)	30-day readmission (n = 81)	p-value
Overall in hospital morbidity	259 (50.0%)	0	208 (47.6%)	51 (63.0%)	**0.012**
Type of complication		0			
Pancreatic fistula	112 (21.6%)		91 (20.8%)	21 (25.9%)	0.311
ISGPF Grade B/C fistula	65 (12.5%)		56 (12.8%)	9 (11.1%)	0.676
Delayed gastric emptying	16 (3.1%)		15 (3.4%)	1 (1.2%)	0.495
Abdominal collection	69 (13.3%)		54 (12.4%)	15 (18.5%)	0.131
Surgical site infection	41 (7.9%)		29 (6.6%)	12 (14.8%)	**0.010**
Chest infection	42 (8.1%)		33 (7.6%)	9 (11.1%)	0.282
Cardiac complications	34 (6.6%)		28 (6.4%)	6 (7.4%)	0.740
Deep venous thrombosis	1 (0.2%)		0 (0%)	1 (0.2%)	1.000
Acute kidney injury	13 (2.5%)		9 (2.1%)	4 (4.9%)	0.131
Cerebrovascular accident	5 (1.0%)		4 (0.9%)	1 (1.2%)	0.572
Arterial pseudoaneurysm	2 (0.4%)		1 (0.2%)	1 (1.2%)	0.299
Gastrointestinal bleeding	22 (4.2%)		18 (4.1%)	4 (4.9%)	0.764
Clavien-Dindo Grade $\geq$ III	70 (13.5%)	0	54 (12.3%)	16 (19.8%)	**0.021**
CCI score	14 (0–22.63)	0	8.66 (0–22.63)	20.91 (0–26.22)	**0.007**
CRP (mg/L)					
Postoperative day 3	140 (70–233)	3	144 (76–237)	185 (104–263)	**0.001**
Before discharge	66 (31–113)	2	65 (31–110)	72 (31–147)	0.413
White Blood Cells Count (G/L)					
Postoperative day 1	14 (11–17)	0	14 (11–17)	13 (11–18)	0.966
Postoperative day 3	11 (9–14)	0	11 (9–13)	12 (10–14)	**0.020**
Before discharge	10 (8–13)	0	10 (8–13)	11 (8–14)	0.151
Total bilirubin (mg/L)					
Postoperative day 1	17 (11–37)	0	17 (10–36)	17 (11–43)	0.776
Postoperative day 3	12 (7–24)	0	12 (7–23)	11 (7–28)	0.720
Before discharge	9 (6–16)	0	9 (6–16)	11 (5–19)	0.621
DFA postoperative day 3 (UI)	41 (14–283)	2	40 (14–272)	47 (14–603)	0.410
Length of hospital stay	9 (7–15)	0	9 (7–15)	11 (8–17)	0.096

Bold p-values are significant at $p < 0.05$. Abbreviations: ISGPF: International Study Group of Pancreatic Fistula; CCI: Comprehensive Complication Index; DFA: Drain Fluid Amylase.

identified pre-operative biliary stent (HR:1.80, 95% CI: 1.35–2.40, $p < 0.001$), history of diabetes (HR: 1.56, 95% CI: 1.14–2.13, $p = 0.006$), pancreatic duct <3 mm (HR:1.48, 95% CI: 1.14–1.92, $p = 0.004$) and increasing patient age (HR: 1.02 per year, 95% CI: 1.00–1.03, $p = 0.014$) as independent predictors of reduced patient survival. After accounting for these factors, readmission within 30 days remained significantly predictive of worse patient survival (HR:1.91; 95% CI:1.38–2.63; $p < 0.001$).

Discussion

In this study, we have developed a simplified risk score to predict unplanned hospital readmission after pancreaticoduodenectomy. The risk score is based on three independent factors from the pre and early post-operative period: history of cardiac disease, serum C-reactive protein on the third post-operative day (CRP-3) and the Comprehensive Complications Index (CCI). A simplified points-based version of the model has been generated to facilitate its clinical application, and stratifies patient according to the risk of readmission.

Pancreaticoduodenectomy is a major surgical procedure associated with significant morbidity in the region of 40%.[12,18–20] In healthcare systems with limited resources and bed shortages such as the NHS, there is constant pressure to discharge patients as soon as possible after surgery. In recent decades, ERAS pathways have been effectively introduced into a wide range of surgical specialties and have been associated with improved outcomes and reduced length of stay, without necessarily impacting on readmission after discharge.[21–26] Unplanned readmission after PD occurs in 16–22% of patients,[20,27–29] and

Table 4 Multivariable analysis of predictive factors associated with 30-day readmission in the derivative cohort

Variable	OR (95% CI)	p	β	95% Bootstrap CI for β[a]
History of cardiac disease	2.12 (1.12–4.56)	**0.048**	0.752	0.113, 1.525
CRP level > 140 mg/L on POD 3	2.34 (1.37–4.35)	**0.002**	0.850	0.315, –1.470
CCI >14	1.70 (1.03–2.85)	**0.036**	0.533	0.002, 1.046

All factors from Tables 2 and 3 with $p < 0.2$ on univariable binary logistic regression analysis were considered for inclusion in a backwards stepwise multivariable model. Pancreatic duct width CT (mm), intra-operative vascular reconstruction, post-operative pancreatic fistula, overall in hospital morbidity, surgical site infection, post-operative acute kidney injury, Clavien-Dindo Grade $\geq$ III and white blood cells count (G/L) on post-operative day 3 were excluded by the stepwise procedure. Bold p-values are significant at $p < 0.05$. Abbreviations: CCI: Comprehensive Complication Index; OR: odds ratio; CI: confidence interval.
[a] After bootstrap resampling (1000 bootstrap samples).

is usually related to a surgical complication. It has been suggested that readmissions up to 90 days after discharge following pancreatic surgery should be reported to capture all patients with postoperative complications.[30] However, in our study there were no unplanned readmissions due to postoperative complications beyond thirty days, and therefore our analysis focussed on this time point. In our study, two-thirds of readmissions were into local non-specialist hospitals, where infrastructure and/or local expertise may hinder prompt treatment of a post-PD complication. Delays in definitive treatment and/or transfer to the specialist centre may negatively impact on patient outcomes and may put patients at risk. It is therefore desirable to identify a subgroup of patients at high risk of readmission after PD, since it may be possible to reduce the probability of readmission by enhancing post-discharge support in such patients.

Several factors associated with hospital readmission after PD have been identified previously, including factors relating to the complexity of the operation (transfusion, blood loss, small pancreatic duct, vascular resection) and/or complicated post-operative recovery (prolonged hospital stay, complications).[20,27,28,30] Surgical complications are particularly important risk factors for readmission, as shown in our study and by others.[19] Importantly, in our study, the majority of complications that resulted in readmission were not diagnosed during the index admission. This is a potential concern, and may be a reflection of the absence of diagnostic clinical features in the early post-operative period. A low grade pancreatic fistula or early delayed gastric emptying may initially present with non-specific symptoms and in the absence of objective clinical and/or laboratory abnormalities, diagnostic imaging may not be undertaken during the index admission. However, it may be clinically and economically justifiable for patients at high risk of readmission (based on our risk score) to undergo CT with oral and intravenous contrast before being discharged, even if they fulfil hospital discharge criteria. Whether any intervention can reduce hospital readmission after major surgery is not clear, but the cost-effectiveness of such intervention should be evaluated prospectively. Hospital readmission after surgery is an indicator of quality in healthcare systems,[31] and carries a significant financial burden. Although it is unlikely that hospital readmission can be completely eliminated,[32,33] it may be possible to improve

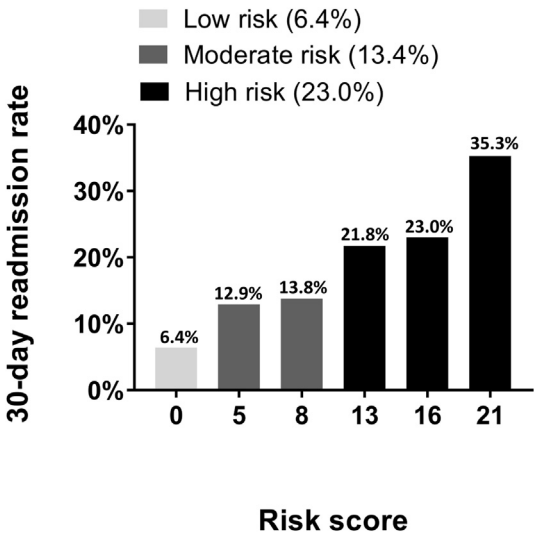

Figure 1 Rate of 30-day hospital readmission after the discharge from the index hospitalisation according to the points-based score system

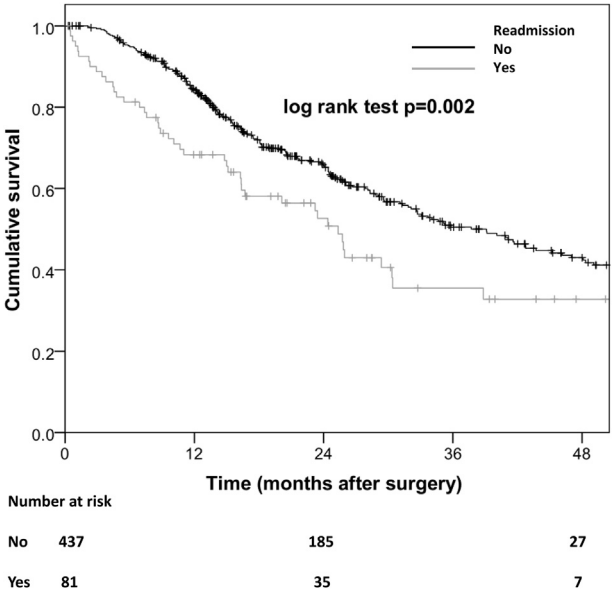

Figure 2 Kaplan–Meier survival curve for groups with and without 30-day hospital readmission after discharge from the index hospitalisation

outcomes by prompt diagnosis of complications using enhanced follow-up (e.g. nurse-led telephone consultation)[34,35] or remote physiological monitoring.[36]

As expected, our analysis showed that complications during the index admission were predictive of unplanned readmission. Interestingly, the comprehensive complication index (CCI) and not the Clavien-Dindo classification was an independent predictor. The Clavien-Dindo system is well-established,[15] but the CCI has been recently developed in an effort to quantify the overall burden of morbidity for an individual patient, and takes the severity of multiple complications into account.[16] CCI has been found to be a predictor of readmission after hepatic,[37] colorectal[38] and orthopaedic surgery,[39] and the results of our study appear to validate its role as a useful measure of complication severity.[15,40]

In our study, a history of cardiac disease was an independent predictor of readmission. Previous studies have also identified a relationship between cardiac disease and post-operative morbidity and hospital readmission[13,41,42] including a meta-analysis by Fisher *et al.* which evaluated the factors associated with readmission after pancreatic surgery.[43] Although the exact mechanism by which patients with cardiac disease are at risk of readmission is unclear, it is likely that such patients have less capacity to respond to complications due to a lower physiological reserve. The relationship between cardiac disease and complications/readmissions after non-cardiac surgery warrants further investigation. The third independent factor in our risk score was CRP measured on the third post-operative day (CRP3). The levels of inflammatory markers at the time of hospital discharge were not associated with readmission in this study. This finding is not altogether unexpected, since a low white cell count has been a component of our ERAS pathway discharge criteria since 2012.

This study has some limitations. First, the risk score has been derived from an analysis of data from a single U.K. centre, and its validity should therefore be tested in other healthcare systems. Second, data-driven cut-off points were used which were based on information from the entire cohort, and this may result in a biased regression coefficient. However, each factor was also tested as a continuous variable, which returned similar results.

In conclusion, we have developed and validated a simple, clinically applicable risk score to accurately predict patients at risk of readmission after pancreaticoduodenectomy. Further work is required to externally validate the score, and prospective studies are necessary to test the impact of enhanced post-discharge interventions on the incidence and/or severity of unplanned readmission in selected high risk patients.

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None.

Conflicts of interest

None declared.

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