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ORIGINAL ARTICLE

Outcomes in pancreatic resection are negatively influenced by pre-operative hospitalization

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Abstract

Background: Quality improvement in high-acuity surgery increasingly relies on clinical pathways to streamline patient care and to maximize cost-efficiency. Yet, it remains unclear whether immediate pre-operative hospitalization (non-elective resection) influences operative performance and to what extent it alters the post-operative course.

Methods: Retrospective case series, cost analysis.University tertiary care referral centre. Four hundred and twelve consecutive pancreatic resections performed for benign and malignant disease between 2001 and 2008. Outcomes for both elective and non-elective operations were scrutinized, and correlated with deviations from our clinical Carepath for Pancreatic Resection. Observed-to-expected (O/E) morbidity ratios were calculated for each.

Results: Overall, 39 patients (10%) required immediate pre-operative hospitalization, 22 (56%) of which were transferred from another hospital. The most common indications were pancreatitis, gastric outlet obstruction, intractable abdominal pain and gastrointestinal bleeding. During a 1- to 2-week hospitalization, 51% of patients underwent endoscopic retrograde cholangio-pancreatography (ERCP), 36% were administered parenteral nutrition, 20% received antibiotics and 15% were transfused blood products. Yet, this pre-operative scenario, at a median cost of $7250 per patient, had no measurable impact on operative performance. Post-operatively, non-elective patients suffered more complications and a higher (O/E) ratio (1.00 vs. 0.93). These outcomes resulted in significantly more deviations from our carepath and an additional $7000 per non-elective case.

Conclusion: Immediate pre-operative hospitalization has no meaningful impact on operative performance; yet, deviations from a standardized clinical pathway are far more likely after non-elective pancreatic resection, and result in more severe clinical and economic outcomes.

Keywords

pancreaticoduodenectomy, pancreatic resection, surgical outcomes, quality, clinical pathway, costs, pancreatic cancer, complications

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Introduction

Quality improvement is an emerging trend, particularly in high-acuity surgery, where comorbid conditions are the norm, operations are technically demanding, and complications are caustic and costly. Traditional process and systems improvements have thus far focused considerably on high volume thresholds and selective regionalization of surgical care, particularly for pancreatic resection and other high-acuity operations.[1–7] However, these initiatives are imprecise and mask the underlying factors that may contribute to better outcomes. Recent data suggests that many high-volume surgical specialty centres utilize clinical pathways to streamline patient care and to maximize cost-efficiency.[8–11] A clinical pathway defines an effective care process for a particular diagnosis or procedure based on evidence-based

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guidelines, and establishes the optimal sequence and timing of interventions by health care providers. Its primary aims are to standardize and improve the quality of patient care, to minimize resource utilization, to shorten hospital stays and to increase cost-effectiveness.[12] Today, these clinical pathways are increasingly relied upon to improve quality and deliver better peri-operative outcomes in pancreatic surgery.[13–15]

Through the collaborative efforts of a dedicated multi-service, specialty team of surgeons, gastroenterologists, anaesthesiologists, pathologists, radiologists, nurses and hospital administrators, a detailed clinical pathway for peri-operative management was recently implemented at our institution. This pathway outlines a standardized management approach for all patients undergoing pancreatic resection based on the tenants of evidence-based medicine. It provides simple guidelines for the management and timely removal of central venous catheters, nasogastric tubes, urinary catheters and intra-abdominal drains; it standardizes peri-operative fluid resuscitation, antibiotic administration, diagnostic testing and initiation of oral intake; finally, it incorporates several patient-centred initiatives, including psychosocial counselling, geriatric consultation and early rehabilitation planning whenever indicated.[6,15]

Today, pancreatic resection is typically performed as an elective operation, usually after a detailed diagnostic evaluation has been conducted in the outpatient setting. However, a subset of patients still requires immediate pre-operative hospitalization (and consequent non-elective resection) for periampullary neoplasms, pancreatitis or cystic conditions that are associated with additional peripancreatic complications (i.e. gastric outlet obstruction, malignant biliary obstruction, malnutrition, hypovolemia, gastrointestinal and intra-abdominal bleeding). While most clinical pathways seek to streamline patient care, to minimize resource utilization and to facilitate early discharge, it remains unclear whether these outcomes can be achieved when patients require immediate pre-operative hospitalization prior to pancreatic resection. Therefore, this study will describe the influence of pre-operative hospitalization on operative performance, the extent to which non-elective resection alters the post-operative clinical course and the attendant costs incurred under the framework of a standardized clinical pathway.

Methods

Patients

Two fellowship-trained pancreato-biliary surgical specialists (M.P.C., C.M.V.) performed 412 consecutive pancreatic resections between October 2001 and March 2008. Final pathological diagnosis revealed a full spectrum of benign and malignant periampullary pathology, most commonly pancreatic ductal adenocarcinoma (n = 131), cystic neoplasm (n = 92) and chronic pancreatitis (n = 61). Other conditions consisted of ampullary adenocarcinoma (n = 34), neuroendocrine tumours (n = 31), distal cholangiocarcinoma (n = 8), duodenal adenocarcinoma (n = 6) and other benign (n = 42) or malignant (n = 7) conditions, such as pancreatic or biliary ductal strictures, adenomas, gastrointestinal stromal tumours and metastatic renal cell carcinoma.

Operations

All pancreatic resections were performed in a reproducible fashion at our institution; these included 272 pancreatoduodenectomies and 124 distal, 9 central and 7 total pancreatectomies. Specific modifications, including technical approaches and management of the pancreatic remnant, have been described in prior studies.[16,17] Pancreatoduodenectomy was frequently performed for pancreatic ductal adenocarcinoma (40%). The most common indications for distal pancreatectomy were cystic neoplasms (44%), primarily intraductal papillary mucinous neoplasia (IPMN) and mucinous cystadenoma (33% and 37% of cystic neoplasms, respectively). Central pancreatectomy was also performed for cystic neoplasms (44%). Total pancreatectomy was usually performed for patients with pancreatic ductal adenocarcinoma in the setting of IPMN (71%).

Clinical pathway

All aspects of care were directed by the operating surgeon according to a standardized Carepath for Pancreatic Resection employed at our institution.[6,15] This pathway outlines a standardized multidisciplinary management approach for all patients, and provides a detailed plan for preoperative assessment and preparation, thromboembolic and antibiotic prophylaxis, peri-operative pain management, as well as the removal of central venous catheters, nasogastric tubes, urinary catheters and intra-abdominal drains. Furthermore, this clinical pathway standardizes patients' peri-operative fluid resuscitation and alimentation, and minimizes diagnostic and laboratory testing. Finally, the pathway incorporates several patient-centred initiatives and provides psychosocial counselling, nutrition consultation, input from medical pancreatologists and early rehabilitation planning whenever indicated.

Data collection

In accordance with guidelines for human subjects research, approval was obtained from the Institutional Review Board at Beth Israel Deaconess Medical Center. Data on pre-operative, intra-operative and post-operative care were prospectively collected for each case. Pre-operative parameters included patient demographics, presenting symptoms, comorbidities, American Society of Anesthesiologists (ASA) classification of physical status,[18] vital signs, laboratory tests, nutritional parameters (i.e. albumin, serum glucose), prior imaging studies and any other diagnostic or therapeutic studies performed. Expected morbidity for each patient was estimated for each of the 412 patients in accordance with the Physiologic and Operative Severity Score for the enUmeration of Mortality and Morbidity (POSSUM score).[19] Intra-operative variables included total operative time, blood loss, fluid administration, transfusion of blood products, anastomotic technique, as well as the use of drains, stents and pharmacological adjuvants. Final disease pathology was determined and reported

to the patient within 1 week following each case. Periampullary (i.e. pancreatic, ampullary, distal common bile duct, duodenal) adenocarcinomas, IPMN with carcinoma *in situ* or invasive malignancy and other metastatic lesions were classified as malignant conditions. Inflammatory disease (i.e. pancreatitis and stricture), periampullary adenomas, IPMN with low- or moderate-grade dysplasia, serous and mucinous cystadenoma and non-invasive neuroendocrine tumours were considered benign conditions. Post-operative events and clinical outcomes were prospectively recorded by an independent research associate. Hospital costs for each patient were obtained using the institution's Casemix TSI data system.

Pre-operative hospitalization

Two distinct clinical presentations manifest based on the level of urgency prior to pancreatic resection. Elective pancreatic resections are performed for those patients, who undergo a detailed diagnostic evaluation in the outpatient setting, and who then present on the day of the index operation for definitive management of periampullary lesions. These clinical presentations are appropriately referred to as 'Elective Resections'. In some circumstances, these elective patients initially present elsewhere, prior to referral to our specialty unit for definitive management.

In contrast, there exists a subset of patients that requires hospitalization immediately prior to pancreatic resection. Some patients may also present elsewhere initially, but are eventually transferred and admitted to our institution for further evaluation. These patients typically undergo inpatient diagnostic evaluations, as well as therapeutic intervention for complications related to their underlying periampullary conditions. Indications include, but are not limited to, gastric outlet obstruction, pancreatitis, malnutrition, gastrointestinal bleeding, obstructive jaundice and cholangitis. When these conditions occur, subsequent diagnostic evaluation (i.e. laboratory and radiological) and therapeutic intervention (i.e. antibiotics, supplemental nutrition, blood transfusion, endoscopic and/or image-guided approaches) is required. Patients with this presentation eventually proceeded to 'Non-Elective Resections', performed several days after hospital admission, but during the index hospitalization at our institution.

Analysis of pre-operative hospitalization

Clinical and economic impact

Three distinct outcomes analyses were performed to reveal the incremental impact of immediate pre-operative hospitalization on operative performance and the extent to which non-elective resection alters the post-operative clinical course. The first analysis examines and compares clinical and economic outcomes for the Elective and Non-Elective groups. Traditional indicators of quality – complications, hospital duration and operative mortality – were scrutinized, as well as other emerging measures of surgical quality: therapeutic and invasive interventions, ICU utilization, patient discharge disposition and hospital readmission rates. Post-operative complications after elective and non-elective resections were graded by an independent reviewer according to the Clavien complication scheme.[20] Similarly, costs accrued before and after surgical intervention were examined for both patient cohorts. These include total and itemized cost metrics, which have been defined elsewhere.[16] Pre-operative hospital costs refer to those costs incurred during the pre-operative hospitalization period and exclude any costs for outpatient diagnostic evaluations. Post-operative hospital costs are defined as those incurred during the index operation, during the post-operative period up to hospital discharge, *plus* any costs incurred during readmissions within 30 days of hospital discharge. Total hospital costs are the aggregate of pre-operative and post-operative hospital costs.

As mentioned above, the incidence and severity of post-operative complications were defined according to the Clavien complication scheme, a reliable and previously validated tool for surgical quality assessment.[20,21] This system describes five grades of clinical severity, based not on duration of stay in the hospital, but rather on the distinction of escalating levels of therapeutic interventions required to treat adverse events. Briefly, 'Minor' complications (i.e. Clavien Grades I and II) correspond to any deviation from the normal post-operative course, which may or may not require pharmacological treatment, including antiemetics, antipyretics, analgesics, diuretics, electrolytes, therapeutic physiotherapy, blood transfusions, total parental nutrition, antibiotics or anticoagulants. 'Moderate' complications (i.e. Clavien Grade III-A) represent those adverse events that require radiological or endoscopic intervention. 'Major' complications (i.e. Clavien Grades III-B, IV, V) are more variable, but refer to those that necessitate surgical intervention, are life-threatening and/or result in death. These complication categories have been described in more detail in a prior study.[15]

Observed-to-expected morbidity

The second outcomes analysis estimates further the clinical impact of immediate pre-operative hosptitalization and subsequent non-elective resection. Details of this novel analysis have been previously published.[6] In summary, differences in patient acuity (i.e. baseline physiology) for the elective and non-elective groups were directly correlated with observed surgical outcomes to reflect the impact of the non-elective scenario on outcomes. Specifically, we compared the actual number of complications incurred to the predicted number of complications – the observed-to-expected (O/E) morbidity ratio – for each patient cohort.

Expected morbidity was predicted for each of the 412 patients based on the POSSUM score. This measure of patient acuity has been validated as a reliable scoring system for estimating morbidity risk in high-acuity surgery, particularly pancreatic resection.[19,22] The risk of developing a post-operative complication (from 0% to 100%) was predicted for each individual patient using the POSSUM score equation. The 'Expected Morbidity' for our practice overall, as well that for elective and non-elective resections, was then estimated by calculating the mean POSSUM

score for the cohort assessed. The actual incidence of post-operative complications ('Observed Morbidity') was also determined for all patients undergoing pancreatic resection within our practice and by resection groups, using the aforementioned Clavien complication scheme.[20] Using the actual incidence of post-operative complications and the mean POSSUM score, O/E morbidity ratios were calculated for elective and non-elective resections. These ratios provide a measure of variance in patient outcomes and reveal areas for process and systems improvement. Ratios equal to 1.00 demonstrate expected, on par, performance. Ratios greater than 1.00 suggest outcomes are worse than expected. Conversely, ratios less than 1.00 suggest outcomes achieved are better than expected.

Deviation-based cost modelling

Peri-operative management for all patients was governed by a standardized Carepath for Pancreatic Resection employed at our institution. Surgical care beyond this baseline process was provided at the discretion of the operating surgeon whenever adverse events or complications mandated further intervention for the benefit of the patient. These deviations (i.e. departures from the expected clinical course) were scrutinized in detail vis à vis deviation-based cost modelling (DBCM).[15]

DBCM specifically merges complication severity with specific duration of stay criteria. When peri-operative management according to our carepath is achieved, 'On-Course' patients either incur no adverse events or suffer only minor complications (i.e. Clavien Grades I or II) and remain hospitalized for only 8 or fewer days after their resections. 'Minor Deviations' represent patients, who experience marginal increases in hospital duration (9 to 12 days), despite having – at most – only minor complications. 'Moderate Deviations' result if patients require additional management beyond 13 days or if moderate complications (i.e. Clavien Grade III-A) occur irrespective of duration of stay. Finally, 'Major Deviations' represent any circumstance in which major complications (i.e. Clavien Grade III-b, IV, or V) occur, regardless of hospital duration.

Hospital duration and costs for each deviation class were compared between elective and non-elective resections using a 'summary' measure of cost-efficiency that combines the relative proportion of each deviation category (on-course to major) with its median hospital cost. This measure provides the weighted-average median duration of stay and cost per patient, and reflects the direct contribution of reducing complications to the overall improvement of cost-effectiveness, as well as within each resection group.

Statistical analysis

Categorical variables were compared using the chi-squared (χ^2, Fischer's exact tests,and univariate logistic regression statistics; continuous variables were compared using analysis of variance (ANOVA), Student's *t*-tests for independent variables and simple linear regression when appropriate. Differences between observed and expected morbidity were assessed with the χ^2 tests, using the method described by Hosmer and Lemeshow to test the goodness of fit.[23] Factors associated with morbidity were calculated based on cross-tabulations using chi-square statistic and Pearson's correlation test. Statistical significance for all analyses was accepted at a P-value < 0.050. Statistical computations were performed using Statistical Package for the Social Sciences 14.0 for Windows (SPSS, Inc., Chicago, IL, USA) and STATA.8.2 for Windows (StataCorp LP, College Station, TX, USA).

Results

Pre-operative hospitalization

Pancreatic resection was performed for 412 patients at our institution between October 2001 and March 2008. The majority (90%) of patients had elective operations (n = 273) and did not require any prior hospitalization; 39 patients (10%), however, required pre-operative hospitalization at our institution directly preceding their pancreatic resections. Males and females underwent resection with relatively equal frequency in each patient cohort. As anticipated, patients presenting for non-elective pancreatic resection were sicker, as judged by the ASA classification of physical status and the POSSUM Physiologic Severity Score (Table 1). This group largely consisted of patients transferred

Table 1 Pre-operative patient characteristics for patients undergoing elective and non-elective pancreatic resection

Pre-operative parameters	Elective (n = 373)	Non-elective (n = 39)	P-value
Age (median, years)	63	59	0.095
	[23–90]	[30–83]	
Gender (%)			
Male	174 (47)	20 (51)	0.350
Female	199 (53)	19 (49)	
ASA physical status (%)			
Class I	5 (1)	0 (0)	0.044
Class II	177 (48)	10 (26)	
Class III	182 (49)	27 (69)	
Class IV	9 (2)	2 (5)	
Final pathology (%)[a]			
Benign	191 (51)	24 (62)	0.144
Malignant	182 (49)	15 (38)	
POSSUM – Physiological Severity Score	19	22	0.023
	[12–40]	[13–34]	

ASA, American Society of Anesthesiologists; POSSUM: Physiologic and Operative Severity Score for the enUmeration of Mortality and Morbidity.[19]

[a]Malignant: periampullary (i.e. pancreatic, ampullary, distal common bile duct, duodenal) adenocarcinomas; intraductal papillary mucinous neoplasms (IPMN) with high-grade dysplasia, carcinoma *in situ*, or invasive malignancy; other metastatic lesions. Benign: inflammatory disease (i.e. pancreatitis and stricture); periampullary adenomas; IPMN with low- or moderate-grade dysplasia; serous and mucinous cystadenoma; non-invasive neuroendocrine tumors.

Table 2 Operative outcomes for elective and non-elective pancreatic resection

Intraoperative outcomes[a]	Elective (n = 373)	Non-elective (n = 39)	P-value
Resection types (%)			
Pancreatoduodenectomy	247 (66)	25 (64)	0.481
Distal pancreatectomy	112 (30)	12 (31)	
Central pancreatectomy	7 (2)	2 (5)	
Total pancreatectomy	7 (2)		
Operative time (minutes)[a]	356	388	0.137
	[76–780]	[152–652]	
Blood loss (ml)[a]	350	400	0.901
	[0–15 000]	[100–1800]	
Blood transfusion (%)	59 (16)	11 (28)	0.047
POSSUM – operative severity score[b]	15	15	0.798
	[13–27]	[13–23]	

POSSUM: Physiologic and Operative Severity Score for the enUmeration of Mortality and Morbidity.[19]
[a]All continuous variables reflect the median for each cohort.

Table 3 Post-operative outcomes for elective and non-elective pancreatic resection

Postoperative outcomes[a]	Elective (n = 373)	Non-elective (n = 39)	P-value
Morbidity (%)	190 (51)	26 (67)	0.043
Mortality (%)	5 (1.3)	0 (0)	0.607
Severity of complications (%)			
None	183 (49)	13 (33)	0.096
Minor	136 (36)	15 (38)	
Moderate	28 (8)	5 (13)	
Major	26 (7)	6 (15)	
Therapeutic interventions (%)			
Antibiotics	102 (27)	16 (41)	0.056
Parenteral nutrition	36 (10)	10 (26)	0.006
Blood transfusion	59 (16)	11 (28)	0.047
Invasive interventions (%)			
CT-guided percutaneous drainage	19 (5)	2 (5)	0.611
Reoperation	15 (4)	5 (13)	0.031
ICU utilization (%)	15 (4)	16 (15)	0.009
Hospital duration (days)			
Pre-operative	0	6	<0.001
Post-operative	8	9	0.007
Total	8	15	<0.001
Discharge disposition (%)			
Home	320 (87)	33 (85)	0.417
Rehabilitation facility	48 (13)	6 (15)	
Readmission (%)	53 (14)	8 (20)	0.202

[a]All continuous variables reflect the median for each cohort.

from another hospital: 22 patients – 56% of non-elective and 5% overall. The most common indications included pancreatitis (n = 14, 35%), gastric outlet obstruction (n = 9, 23%), intractable abdominal pain (n = 6, 15%), gastrointestinal bleeding (n = 5, 13%) and jaundice (n = 4, 10%). One patient presented with intractable hypoglycemia as a result of insulinoma. While the majority (62%) of these non-elective patients had benign conditions, a considerable proportion (38%) was eventually found to harbour malignant tumours, a rate not significantly different from that of the elective cohort (49%, P = 0.144).

Pre-operative hospitalization did not significantly alter patient acuity, as measured by the POSSUM Physiologic Score. On admission, the acuity score for non-elective patients was 22 (median), compared with 21 at the time of operative intervention (P = 0.601). During the in-patient process, 51% of patients (n = 20) underwent endoscopic retrograde cholangiopancreatography (ERCP) with biliary or pancreatic enteric drainage for unresolved jaundice or failed drainage procedures; 36% (n = 14) were administered parenteral nutritional support; 20% (n = 8) received intravenous antibiotics; and 15% (n = 6) were transfused blood products. These pre-operative interventions were typically provided during a 1- to 2-weeks hospitalization (median: 6 days, range: 1–19 days) at a considerable cost (median: $7250; range: $1201–$21 879).

Operative outcomes

Pancreatoduodenectomy, distal and central pancreatectomy were performed with relatively equal frequency among elective and non-elective patients; total pancreatectomy was not performed in a non-elective fashion (Table 2). All operative outcomes were equivalent between the two patient cohorts. Intra-operative blood loss was similar during elective and non-elective resections – 350 and 400 ml, respectively – but, non-elective patients were transfused intra-operatively more frequently (28% vs. 16%, P = 0.047). Despite this approach, surgical performance, as judged by the median POSSUM Operative Severity Score, was equal between the patient cohorts (15 each). These findings indicate that despite increased patient acuity for non-elective resections, this scenario has no measurable impact on operative performance.

Post-operative outcomes

Overall

Clinical outcomes for all 412 patients met or exceeded current benchmark standards for pancreatic resection.[24,25] Overall, 216 patients (52%) developed complications of any severity; 102 patients (25%) had Grade I complications, 49 Grade II (12%), 39 Grade III (10%), 21 Grade IV (5%) and 5 Grade V (1.2%). Thus, when complications occurred, the majority (70%) were of minor severity (i.e. Clavien Grades I or II) – 151 patients in total (37% overall) – and did not mandate any invasive or aggressive

Table 4 Economic outcomes for elective and non-elective pancreatic resection

Hospital costs[a]	Elective	Non-elective	*P*-value
Radiology	$339	$734	0.807
Laboratory	$513	$684	0.407
Pharmacy	$775	$1 308	0.707
Transfusion	$134	$630	0.563
ICU	$794	$1 293	0.867
Operating room	$4 389	$4 920	0.036
Room	$6 628	$9 891	0.013
Overall			
Pre-operative	–	$7 250	–
Post-operative	$17 963	$22 674	0.646
Total	$17 963	$31 209	0.024
Total cost-increase	–	$13 246	–

[a]All cost metrics reflect the median for each cohort.

Table 5 Observed-to-expected (O/E) Morbidity for elective and non-elective pancreatic resections

	Overall	Elective	Non-elective
Patients	412	373	39
Risk of complication[a]	56.1%	54.7%	65.8%
Expected morbidity	231	204	26
Observed morbidity[b]	216	190	26
O/E morbidity ratio	0.94	0.93	1.00

[a]Reflects mean POSSUM score for patient cohort.[19]
[b]Represents actual incidence of complications according to the Clavien complication scheme.[20]
$\chi^2 = 0.96$; 1 d.f.; $P = 0.317$.

interventions. The remainder (30% of complicated patients, 16% overall) suffered moderate or major complications (i.e. Clavien Grades III, IV, or V).

Management in intensive care settings and reoperation were seldom required (5% each), and only five patients overall (1.2%) succumbed. The median post-operative hospital duration was 8 days (range: 1–61 days) and at the time of hospital discharge, 87% of patients returned home, whereas 13% required additional care in rehabilitation facilities. Hospital readmission (15%) was also infrequent. These benchmark standards were achieved at a total hospital cost of $18 136 per patient (median).

Non-elective resections

When non-elective pancreatic resections were performed, two-thirds ($n = 26$) resulted in at least one complication of any severity; 39% of patients of this cohort suffered minor complications, 13% had moderate complications and 15% developed major complications. The most common complications among this distinct group included were oliguria/hypotension (38%), clinically relevant pancreatic fistulae (20%), post-operative ileus (17%) and wound infections (13%). The median post-operative hospital duration for these resections was 9 days (range: 5–61). The majority of patients, who required immediate pre-operative hospitalization, returned home (85%) at the time of hospital discharge; 15% required further management at rehabilitation facilities. Hospital readmission occurred in 20% of cases and no perioperative deaths were observed. The median post-operative cost for non-elective resections was $22 674 (range: $13 951 to $46 610).

Elective versus non-elective

Clinical and economic outcomes were directly compared for elective and non-elective pancreatic resections (Tables 3 and 4). The overall incidence of post-operative complications was significantly greater after non-elective resections compared with elective cases (67% vs. 51%, $P = 0.043$). Deeper analysis of this scenario reveals a trend towards more severe complications, as patients who required an immediate pre-operative hospitalization were more than twice as likely to develop moderate and/or major complications (OR 2.32, 95% CI 1.09 to 4.94, $P = 0.025$). These patients subsequently required more antibiotic therapy, supplemental parenteral nutritional support and blood transfusions than patients who underwent elective resections. Similarly, more aggressive interventions were mandated after non-elective resections, including reoperation and management in intensive care settings; rates of CT-guided percutaneous drainage, however, were equivalent between the groups. These outcomes ultimately prolonged post-operative hospital stays, yet had no measurable impact on hospital discharge disposition or readmission.

A detailed economic analysis was performed to determine the incremental impact of non-elective resections. In sum, these operations were associated with a total cost increase of $13 246 per patient (median), the majority – $7250 or 55% – of which was as a result of pre-operative management, whereas $5996 or 45% can be attributed to differences in post-operative care. These costs largely reflect increased rates of reoperation (i.e. OR costs) and longer hospitalizations (i.e. room costs) after non-elective resections; all other cost metrics were not significantly different between the groups.

Observed-to-expected morbidity

Given these distinct clinical and economic outcomes for non-elective resections, a detailed quality analysis was conducted to determine the extent to which these outcomes met or fell short of benchmark standards for pancreatic resection. In summary, observed morbidity was merged with expected,and compared between the patient cohorts. 'Expected' morbidity (mean POSSUM score) for all patients undergoing pancreatic resection within our practice equaled 56.1% (Table 5). Thus, predictive risk assessment estimated that 231 (of 412 total) patients would develop at least one post-operative complication. This prediction was accurate, as 216 patients actually developed a complication. Consequently, the overall O/E morbidity ratio was 0.94 – marginally better than expected.

Table 6 Deviation-Based Cost Modelling (DBCM) for comparison of elective and non-elective pancreatic resections

DBCM[a]	Elective (n = 373)	Non-elective (n = 39)	P-value
Deviation mix (%)			
On-course	234 (63)	16 (41)	0.040
Minor deviation	57 (15)	8 (20)	
Moderate deviation	46 (12)	10 (26)	
Major deviation	36 (10)	5 (13)	
On-course			
Hospital duration	7 days	8 days	0.128
Post-operative hospital costs	$16 782	$20 508	0.363
Minor deviation			
Hospital duration	9 days	10 days	0.487
Total hospital costs	$18 834	$21 562	0.792
Moderate deviation			
Hospital duration	14 days	14 days	0.884
Post-operative hospital costs	$27 703	$31 725	0.925
Major deviation			
Hospital duration	9 days	15 days	0.159
Post-operative hospital costs	$28 864	$44 591	0.852
Hospital duration (weighted-average)	8.4	10.8	–
Duration of stay increase (for non-elective cases)	2.4		
Hospital costs (weighted-average)	$19 608	$26 688	–
Cost increase (for non-elective cases)	$7 079		

[a]Described in full detail by Vanounou *et al.*[15]

O/E morbidity ratios were then calculated separately for elective and non-elective resections. For elective resections, this ratio was 0.93; thus, outcomes for this group of patients were slightly better than anticipated. For non-elective resections, the ratio was 1.00 and, therefore, matched expected standards. However, the difference between elective and non-elective resections with respect to O/E ratios was not statistically significant.

Deviation-based cost modelling

In order to describe the extent to which immediate preoperative hospitalization alters the postoperative clinical course, outcomes for elective and non-elective resections were further scrutinized within the framework of our institutional standardized Carepath for Pancreatic Resection. This analysis was conducted by employing DBCM, a validated quality analysis tool for measuring the incremental impact of process improvement initiatives on hospital duration and costs. Overall, 61% of patients (n = 250) experienced an unaltered clinical course (i.e. 'on-course'). Deviations occurred occasionally, but were usually classified as 'minor deviations' (n = 65, 16%) or 'moderate deviations' (n = 56, 14%); 'major deviations' occurred only 10% of the time (n = 41).

When outcomes for elective and non-elective resections were juxtaposed, the incidence and severity of deviations was substantially greater after non-elective cases (Table 6). Within each deviation category, non-elective patients suffered longer hospital stays and incurred greater costs, yet these differences were not statistically significant. However, the weighted-average for hospital duration and costs distinguishes the full impact of complications after elective and non-elective resections. The weighted-average median hospital duration and costs after non-elective resections were 10.8 days and $26 688, respectively; those after elective resections were 8.4 days and $19 608. Thus, the incremental impact of complications after non-elective resections was roughly a 2-day increase in hospital duration and a $7000 cost-increase per patient.

Discussion

Standardized peri-operative clinical pathways have emerged as an effective method to minimize variations in care, reduce duration of stay, curtail excessive resource utilization and improve overall cost-efficiencies.[1–6] The putative benefits of these management approaches have been described in the clinical literature, although most of these findings are derived from non-randomized comparison studies, with Level II evidence at best.[7–15] In one particular study, Pritts *et al.* describe their experience with the development and implementation of a clinical pathway for small and large bowel resection.[8] Their work uniquely compares a pathway group with 'both' a pre-pathway group and a non-pathway group (patients in the year after pathway implementation, but not

included on the pathway). Significant differences between the groups were observed with respect to duration of stay and costs. Pathway patients experienced shorter hospital stays and considerable cost-savings, as compared with non-pathway patients. These findings have been reproduced in other studies and support the use of clinical pathways for many surgical procedures.

Our group has previously published its experience with a clinical Carepath for Pancreatic Resection. In this analysis, pathway implementation contributed to a 1-day 'decrease' in median hospital stay and $5500 cost-savings per patient.[15] DBCM, however, reveals that these improvements were achieved through reductions in pathway deviations. As fewer deviations occurred overall, more patients remained 'On Course'; this improvement in the deviation mix was associated with parallel reductions in median hospital duration and costs. Deeper analysis demonstrates that one-half of the overall cost-savings could be attributed specifically to pathway implementation; the remainder was associated with general process and system improvements in surgical care independent of the clinical pathway (i.e. secular trends).

Through this rigorous analysis, we realized that a distinct subset of patients requires pre-operative hospitalization immediately for peri-pancreatic complications, such as gastric outlet obstruction, malignant biliary obstruction, malnutrition, hypovolemia and gastrointestinal bleeding immediately preceding pancreatic resection. Like most clinical pathways, our Carepath for Pancreatic Resection is based on evidence-based guidelines for patients undergoing 'elective' pancreatic operations; it had not been evaluated exclusively for non-elective resections, nor have others. Consequently, it remained unclear whether immediate pre-operative hospitalization and the ensuing non-elective resection negatively influence the post-operative clinical course. Therefore, we sought to describe the impact of pre-operative hospitalization on operative performance and the extent to which non-elective resection results in post-operative deviations under the framework of a standardized clinical pathway.

A detailed analysis of the non-elective operative scenario was conducted and demonstrates that patients that require immediate pre-operative hospitalization comprise 10% of all pancreatic resections. These patients frequently had pancreatitis, gastric outlet obstruction, intractable abdominal pain, gastrointestinal bleeding and jaundice, which prompted early therapeutic intervention, including intravenous antibiotics, supplemental parenteral nutritional support, blood transfusion and endoscopic procedures to facilitate biliary or pancreatic enteric drainage. Despite more patients being younger and harbouring benign pathologic conditions, these patients were sicker. Pre-operative hospitalization at our institution alone was approximately 1 week in duration and typically cost more than $7000; yet, it did not significantly improve pre-operative patient acuity metrics. Although patients presenting for non-elective resections demonstrated greater patient acuity, this fact did not influence operative performance measures. All operative outcomes for non-elective resections were equivalent to those for elective cases, most notably operative time and blood loss. Pre-operative hospitalization in this scenario had no measurable impact on operative outcomes and may, in fact, have helped safeguard against the natural predisposition of these genuinely aggressive pancreatic pathological conditions.

Post-operative complications occurred with significantly higher frequency after non-elective pancreatic resections and showed a trend towards greater severity. As a result, these patients required more post-operative therapeutic interventions, such as antibiotic therapy, supplemental parenteral nutritional support and blood transfusion. More aggressive interventions were also employed after non-elective resections, including ICU management and reoperation. These differences are reflected by longer postoperative hospital stays and costs, nearly $5000 more per patient.

A contemporary O/E quality analysis demonstrates further that although there was no significant difference between elective and non-elective resections with respect to O/E ratios, surgical quality for non-elective resections was on par with that of the elective cohort, but did not exceed benchmark standards or surpass anticipated outcomes. This specific analysis indicates that improvements in quality for non-elective resections can still be achieved.

DBCM was performed to determine whether immediate pre-operative hospitalization and non-elective pancreatic resection contribute to deviations in surgical care. DBCM demonstrates that non-elective pancreatic resection alters the post-operative clinical course, but does not significantly change the clinical and economic nature of each pathway deviation. Overall, non-elective patients suffered longer hospital stays and incurred greater costs; yet, within each deviation category, these differences were not statistically significant. Minor deviations behaved in a similar fashion after elective and non-elective resections; as did moderate and major deviations. Therefore, immediate pre-operative hospitalization and subsequent non-elective resection exact their influence on the postoperative clinical course by varying the incidence of pathway deviations. This lone effect, overall, causes roughly a 2-day increase in hospital duration and a $7000 cost-increase per patient.

While the findings of this study show a clear impact in terms of the cost to the health care system for the non-elective scenario, other limiting factors, which we could not adequately address, may also be in play. For instance, it is unclear how many patients presenting with pancreatic conditions are actually hospitalized initially for definitive diagnosis and temporary management. In our practice, 10% of patients were hospitalized immediately prior to pancreatic resection; yet, this percentage underestimates the true incidence of pre-operative hospitalization. We were unable to precisely account for the patients, in either the elective or non-elective cohort, who were hospitalized elsewhere at other medical institutions prior to referral our surgical specialty center. One might estimate that 15–20% of patients follow this pattern, but this will vary across medical centres and among regional populations. Furthermore, the cost of outpatient assessments, diagnostic

imaging and pre-operative palliative procedures performed at other institutions contributes further to the cost-quality equation. These costs, however, could not be included in our analysis. Nevertheless, although these costs are relevant, we surmise that they likely represent only a small fraction of the overall cost of surgical care.

Going forward, process improvement initiatives, which target the non-elective operative scenario, can – and will – be instrumental in streamlining patient care and maximizing cost-efficiency. Patients requiring immediate pre-operative hospitalization may have difficulty adhering to the stringent and structured guidelines of a standardized clinical pathway and will potentially benefit from efforts that reduce pathway deviations. For example, patients at-risk for haemodynamic compromise, clinically relevant pancreatic fistulae and wound infection, who undergo non-elective pancreatic resection, should be managed proactively in the perioperative period. This is particularly important in an era where, because of the pressures for regionalization of expertise in care, high-volume specialty surgical centers can expect more hospital-to-hospital transfers for urgent management of peripancreatic conditions.

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Conflicts of interest

None declared.

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