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ORIGINAL ARTICLE

Cost of postoperative ileus following colorectal surgery: A cost analysis in the Australian public hospital setting

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Abstract

Aim: Postoperative ileus (POI) following surgery results in significant morbidity, drastically increasing hospital costs. As there are no specific Australian data, this study aimed to measure the cost of POI after colorectal surgery in an Australian public hospital.

Methods: A cost analysis was performed, for major elective colorectal surgical cases between 2018 and 2021 at the Royal Adelaide Hospital. POI was defined as not achieving GI-2, the validated composite measure, by postoperative day 4. Demographics, length of stay and 30-day complications were recorded retrospectively. Costings in Australian dollars were collected from comprehensive hospital billing data. Univariate and multivariate analyses were performed.

Results: Of the 415 patients included, 34.9% (n = 145) developed POI. POI was more prevalent in males, smokers, previous intra-abdominal surgery, and converted laparoscopic surgery ($p < 0.05$). POI was associated with increased length of stay (8 vs. 5 days, $p < 0.001$) and with higher rates of complications such as pneumonia (15.2% vs. 8.1%, $p = 0.027$). Total cost of inpatient care was 26.4% higher after POI (AU$37,690 vs. AU$29,822, $p < 0.001$). POI was associated with increased staffing costs, as well as diagnostics, pharmacy, and hospital services. On multivariate analysis POI, elderly patients, stoma formation, large bowel surgery, prolonged theatre time, complications and length of stay were predictive of increased costs ($p < 0.05$).

Conclusion: In Australia, POI is significantly associated with increased complications and higher costs due to prolonged hospital stay and increased healthcare resource utilisation. Efforts to reduce POI rates could diminish its morbidity and associated expenses, decreasing the burden on the healthcare system.

KEYWORDS
colorectal, Cost, financial, ileus, surgery

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INTRODUCTION

One of the most frequent and morbid complications following abdominal surgery is postoperative ileus (POI), resulting from impaired gastrointestinal transit [1]. The principal features of POI include distention of the abdomen, intolerance of oral intake, nausea and vomiting, and absence of flatus or stool [2]. Reported incidences of POI range between 7% and 27%, even in the setting of enhanced recovery protocols [3–5]. The highest incidence of POI is seen after colorectal surgery, due to multiple patient-related, operative and postoperative factors [3, 5–8]. Colorectal surgery specific factors such as handling of the bowel, splenic flexure mobilisation, stoma formation, open approach and rectal resections are known to predispose to POI [6, 7, 9].

POI increases the risk of pneumonia, and the delay of adequate nutritional intake contributes to wound healing impairment and anastomotic failure [2, 10]. Furthermore, POI leads to higher risk of organ failure (such as renal and hepatic failure), prolongs hospital stay and increases 30-day readmission and mortality rates [2, 10]. Furthermore, delayed gastrointestinal recovery such as uncomplicated POI, directly impedes recovery of patient autonomy and subsequent discharge [11]. Preventing POI from occurring could reduce delayed discharges by 33%, readmissions by 21% and mortality by 20% [10].

The morbidity associated with POI leads to a significant financial burden on healthcare systems. Previous studies have demonstrated a >50% increase in hospital costs related to additional expenses for medical, nursing, allied health, radiology and pharmacy services. POI as a single complication is estimated to cost over US$750 million per year in the US alone [12–16]. To date, no Australian POI cost reports have been published. Therefore, the aim of this study was to investigate the financial implications of POI after colorectal surgery in a public hospital in Adelaide, Australia.

What does this paper add to the literature?

This original paper demonstrates the financial impact of postoperative ileus (POI) in an Australian institution. Previous literature, from around the globe, uses ICD-9 codes to diagnose POI. We use a strict clinical definition, GI-2 (validated composite measure of time to tolerance of diet and first stool) to accurately diagnose POI.

METHODS

This study is reported using the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) guidelines [17] and was approved by the Central Adelaide Local Health Network (CALHN) Human Research Ethics Committee.

Patient selection and definitions

This was a single-centre retrospective study performed at the Royal Adelaide Hospital (RAH), Australia. The RAH Colorectal Unit performs over 300 major colorectal procedures per year. The RAH is one of four major public hospitals in South Australia performing colorectal surgery with colorectal specialists. Considered for inclusion were patients operated electively between February 2018 and March 2021 who were identified from the admission lists of the department. POI was defined using the validated composite score GI-2, a measure of passage of stool and 24-h tolerance of oral diet [18]. GI-2 was calculated retrospectively from medical records, for analysis. POI was defined as a patient not achieving GI-2 by postoperative day four, based on the definition by Vather et al. [19]. Patients discharged prior to achieving GI-2 were considered to not have POI. Diagnosis was corroborated with established prospective morbidity audits. All patients at the RAH, are placed on an enhanced recovery pathway (ERP). Patients undergoing colonic resections receive bowel preparation with the addition of a sodium phosphate (Fleet; Prestige Consumer Healthcare Inc.) enema on admission, with left-sided resections not receiving an enema. The ERP protocol is provided in Table S1.

Inclusion and exclusion criteria

Patients 18 years and older, undergoing elective major bowel surgery involving large bowel resections, and formation or closure of stoma were included. Patients were excluded if they underwent emergency surgery or minor elective surgery such as examination under anaesthesia, appendicectomy, haemorrhoidectomy or fistula surgery. Small bowel resections were excluded to focus on colorectal procedures and reduce heterogeneity of the data. Pelvic exenterations were also excluded due to increased morbidity and length of stay that would skew the data and make it less generalisable to other public hospital settings. Robotic cases were excluded as they are performed offsite and transferred to the RAH for postoperative care, making cost analysis between the two sites unreliable. Patient selection is displayed in Figure 1.

Data collection

Data was collected from admission records, prospective morbidity and mortality audits and from electronic and paper medical records, based on known risk factors for POI from the literature [5–7]. Baseline data that was collected included age, gender, body mass index (BMI), smoking history, congestive cardiac failure (CCF) within the last 30 days, chronic obstructive pulmonary disease (COPD), hypertension requiring medication, diabetes mellitus and previous abdominal surgery. Other preoperative variables included haemoglobin and albumin levels. Intraoperative data included the diagnosis (benign or

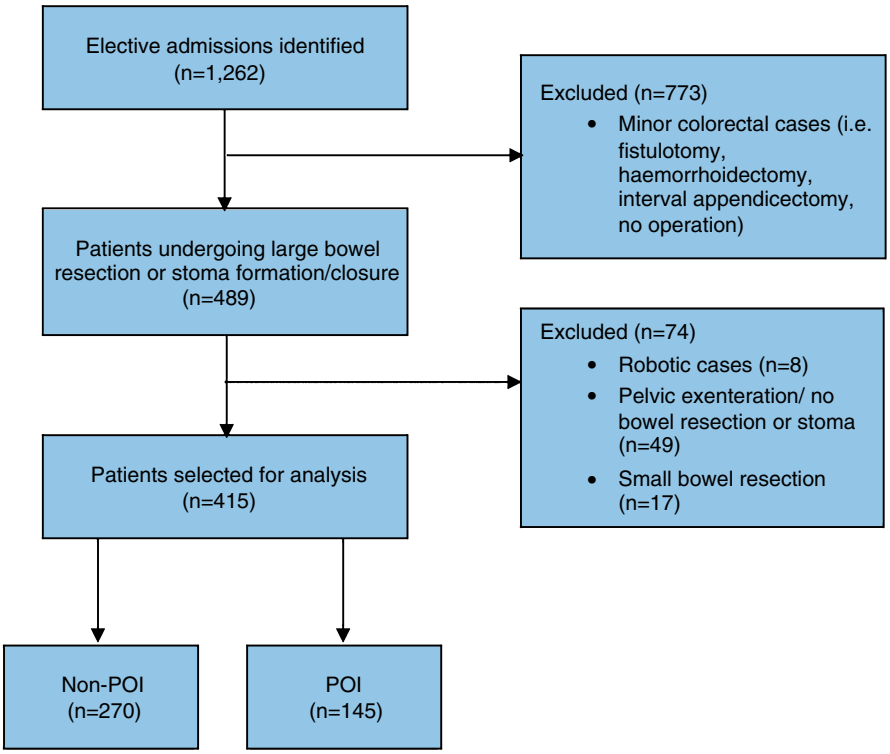

FIGURE 1 Patient selection for patients between February 2018 and March 2021.

malignant), approach of surgery (open/laparoscopic), conversion from laparoscopic to open, procedure type, incidence and type of stoma, and duration in theatre. Data on use of patient controlled analgesia (PCA), transversus abdominis plane (TAP) catheters, as well as intra- and postoperative day 1–4 use of opioids in morphine equivalents was collected. Postoperative outcomes included intensive care admission, return to theatre, length of stay, 30-day complications, Clavien-Dindo (CD) grades, and readmission rates [20].

Outcomes

The primary outcome was the total cost of inpatient stay per patient in Australian dollars (AU$). Costs were adjusted to 2021 Australian dollars for consumer price inflation (~0.86%–4.54% over the study period) [21]. Subgroup analyses were performed for the total cost of inpatient stay excluding 'fixed' costs of theatre, depreciation and nonclinical costs, as these do not reflect the cost of ileus per se, to identify the attributable medical costs of POI. Total inpatient cost per patient excluding CD grade ≥3 complications, was performed to attempt to identify POI attributable costs without significant surgical complication. Subgroup analysis was also performed on expenses for medical, nursing and allied health staff, critical care, theatre, imaging, pathology, pharmacy, supplies, hospital services, nonclinical and depreciation individually. Explanation and definitions of these costs is provided in Table S2. Individual patient costs, separated into expenses per category were received from billing data by the Business Intelligence and Performance Reporting Unit, CALHN. These costs represent hospital costs per patient, prior to reimbursement from private insurers.

Statistical analysis

Patients with and without POI were compared, and cost of POI per patient was calculated. Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 28.0 (IBM Corp). Descriptive statistics are reported as mean (SD) or median (IQR [range]) for continuous variables and categorical variables as frequency (percentage). Categorical variables were analysed using the Fisher's exact (when $n < 5$) and Chi-squared tests. Continuous variables were analysed with the Student's *t*-test or Mann–Whitney U test depending on the normality of the data (Shapiro–Wilk test). Costs were presented as mean (SD), as per the CHEERS guidelines. [17] Univariate and multivariate linear regression analyses were performed on variables chosen a priori on log-normal transformed total cost of inpatient stay, to determine independent predictors of total cost of inpatient stay. Statistical significance was accepted at $p < 0.05$.

RESULTS

Financial costing data were retrieved for all 415 eligible patients undergoing elective surgery in the study period, of whom 145 (34.9%) experienced POI. Patients who suffered POI were more frequently male, active or ex-smokers, and more had previous abdominal surgery ($p < 0.05$ for all characteristics). POI patients also underwent laparoscopic converted to open surgery more frequently (30.6% vs. 10.7%, $p < 0.001$) and underwent reversal of Hartmann's procedure or reversal of ileostomy and abdominoperineal resection more commonly ($p = 0.041$). Patients suffering POI were more likely to have an increase in theatre time

TABLE 1 Comparison of baseline patient characteristics and operative data

Variable	Non-POI ($n = 270$)	POI ($n = 145$)	p-value
Age; year	64 (52–73[18–92])	66 (58–74 [20–94])	0.121
Gender			0.021
Female	121 (44.8%)	48 (33.1%)	
Male	149 (55.2%)	97 (66.9%)	
ASA			0.714
I	7 (2.6%)	3 (2.1%)	
II	137 (50.7%)	66 (45.0%)	
III	123 (45.6%)	74 (51.0%)	
IV	3 (1.1%)	2 (1.4%)	
Smoking history			0.015
Active	47 (17.4%)	33 (22.8%)	
Ex-smoker (>6 weeks)	86 (31.9%)	60 (41.4%)	
BMI; kg/m^2	27.1 (23.9–31.2 [15.9–58.8])	27.3 (24.5–31.9 [15.9–63.7])	0.266
CCF within last 30 days	6 (2.2%)	4 (2.8%)	0.745
COPD	17 (6.3%)	17 (11.7%)	0.055
Hypertension requiring medication	111 (41.1%)	70 (48.3%)	0.161
Diabetes mellitus			0.546
Prescribed tablets	58 (21.5%)	27 (18.6%)	
Prescribed insulin	2 (0.7%)	0 (0.0%)	
Undergone previous abdominal surgery	151 (55.9%)	102 (70.3%)	0.004
Preoperative haemoglobin; g/l	136 (123–145 [81–178])	136 (123–149 [82–176])	0.442
Missing	*0*	*1*	
Preoperative albumin; g/l	37 (34–40 [19–49])	37 (34–39 [20–49])	0.932
Missing	*7*	*8*	
Malignancy diagnosed	150 (55.6%)	75 (51.7%)	0.455
Surgical approach			0.282
Open	121 (44.8%)	73 (50.3%)	
Laparoscopic	149 (55.2%)	72 (49.7%)	
Conversion from laparoscopic to open procedure[a]	16 (10.7%)	22 (30.6%)	<0.001
Operations			0.041
Right-sided (ileocolic resection, extended/right hemicolectomy, transverse colectomy, subtotal colectomy)	92 (34.1%)	52 (35.9%)	
Left sided (left hemicolectomy, sigmoidectomy, anterior resection)	85 (31.5%)	38 (26.2%)	
Total colectomy, pan-proctocolectomy, completion colectomy	22 (8.1%)	5 (3.4%)	
Reversal of Hartmann's procedure	19 (7.0%)	18 (12.4%)	
Reversal of ileostomy	40 (14.8%)	27 (18.6%)	
Abdominoperineal resection	1 (0.4%)	3 (2.1%)	
Formation of stoma	11 (4.1%)	2 (1.4%)	
Stoma formed	59 (21.9%)	25 (17.2%)	0.265
Stoma type			0.416
Ileostomy	43 (72.9%)	16 (64.0%)	
Colostomy	16 (27.1%)	9 (36.0%)	
Theatre time; min	147.5 (109.0–193.5 [29.0–433.0])	163.0 (128.0–214.0 [45.0–385.0])	0.021

(Continues)

TABLE 1 (Continued)

Variable	Non-POI ($n = 270$)	POI ($n = 145$)	p-value
Intraoperative and recovery opioid use; MEQ	120.0 (91–157.5 [20.0–806.0])	126.0 (90.4–169.5 [20.0–385.0])	0.200
Total opioid use POD 1-4; MEQ	120.0 (54.25–229.0 [0–1208.0])	199.25 (99.75–394.88 [0–1821.2])	<0.001
PCA	54 (25.2%)	36 (30.8%)	0.279
Missing	*56*	*28*	
TAP catheters	83 (43.5%)	58 (54.2%)	0.075
Missing	*79*	*33*	
STIMULAX/PyRICo-P Trial [22, 23]	102 (37.8%)	51 (35.2%)	0.600

Note: Values are median (IQR [range]), mean (SD) or number (proportion).

Abbreviations: ASA, American Society of Anaesthesiologists physical status; BMI, body mass index; CCF, congestive cardiac failure; COPD, chronic obstructive pulmonary disease; MEQ, morphine equivalents; PCA, patient controlled anaesthesia; POD, postoperative day; POI, postoperative ileus; TAP, transversus abdominis plane.

[a]$n = 146$ for non-POI; $n = 91$ for POI.

(163.0 vs. 147.5 min, $p = 0.021$), and increased amount of postoperative day one to four analgesia given (119.25 vs. 120.0 MEQ, $p < 0.001$). Patients participating in the STIMULAX and PyRICo-P trials at our institution had equal distribution between non-POI and POI groups [22,23]. These and other baseline characteristics and differences between the POI and non-POI groups are presented in Table 1.

Table 2 shows the comparison of postoperative outcomes and complications between the two groups. The non-POI group had a median length of stay of 5 (IQR (3–7), Range [1–47]) days compared to 8 (IQR (6–11), Range [3–60]) days in the POI group ($p < 0.001$). Patients diagnosed with POI required total parenteral nutrition more frequently (3.4% vs. 0.4%, $p = 0.021$). Patients with POI had higher CD complication grades, mostly CD II, compared to patients without POI ($p < 0.001$). When excluding POI as a complication, the statistical difference in highest CD complication grade remained ($p = 0.016$). Patients diagnosed with POI had more urinary tract infections (6.2% vs. 1.1%, $p = 0.005$), pneumonia or respiratory failure (15.2% vs. 8.1%, $p = 0.027$), cardiac complications (7.6% vs. 1.5%, $p = 0.004$) and deep vein thrombosis or venous thromboembolisms (2.8% vs. 0.4%, $p = 0.053$).

Table 3 demonstrates the difference in cost of inpatient stay. The POI group had a significantly higher mean total cost of inpatient stay of AU$37,689.87 per patient compared to the non-POI group of AU$29,821.70 ($p < 0.001$), a 26.4% or AU$7,868.17 increase in total cost. Individual breakdown of cost demonstrated increased expenses of medical, nursing and allied health in the POI group. Pharmacy, supplies, hospital services, and nonclinical costs were also significantly higher in the POI group. When excluding theatre, depreciation and nonclinical costs there was a 44.5% (AU$6,174.13) increase in cost in the POI group (AU$20,059.16 vs. AU$13,885.03, $p < 0.001$). When analysing the total cost of inpatient stay, excluding patients with CD grade >3 complications, there was a 27% (AU$7,159) increase in patients with POI.

Table 4 displays the results of the multivariate analysis. On multivariate linear regression analysis age ≥65 years old ($p = 0.032$), large bowel surgery ($p = 0.001$), stoma formation ($p < 0.001$), duration of theatre (>150 min) ($p < 0.001$), POI ($p = 0.034$), CD grade ≥3 ($p = 0.002$), and prolonged length of hospital stay ≥6 days ($p < 0.001$) were independently predictive of a total increased cost of stay.

DISCUSSION

This study confirms that in Australia, as also reported internationally, the financial burden of POI is significant, increasing total hospital cost per patient by 26.4%. This is a result of significant increases in length of hospital stay and more complications suffered by POI patients.

The 34.9% POI rate in our study is higher than in previous reports (8.5%–27%) [12–16], which could reflect the different POI definitions used, the inclusion of minor procedures in other studies, and under-reporting of POI. This may reflect that fact that many of the patients in the current study participated in clinical trials [22, 23] specifically investigating POI (an interest of our research group), the strict POI definition used according to GI-2, and the fact that complications in our Department are recorded prospectively. Mao et al. [16] reported a POI rate of 27%, also using strict criteria of symptoms for POI diagnosis such as nausea or vomiting, tolerance of solid diet, abdominal distension, absence of flatus and stools, and radiological evidence on X-ray or computed tomography. Their POI rate is comparable to that of the current study, likely reflecting the prospective collection and similar detailed definition of POI. Studies using GI-2 to define POI following colorectal surgery, have reported rates of 10.1%–28.8% [24, 25]. This rate differs from our reported rate, possibly due to the exclusion of patients receiving a stoma [24] and benign procedures in these other studies [25]. Other costing papers have reported lower POI rates of 8.5%–24%, however, often collected retrospectively and using ICD-9 diagnostic codes rather than using clinical signs and symptoms to diagnose POI, leading to potential for underestimation of POI rate and the associated financial burden [12–15]. Also, these papers reported on a mix of surgical

TABLE 2 Comparison of 30-day outcome and complication data

Variable	Non-POI ($n = 270$)	POI ($n = 145$)	p-value
GI-2	3 (2–4 [0–4])	6 (5–7 [3–12])	<0.001
ICU admission required	9 (3.3%)	11 (7.6%)	0.054
Transfusion required	8 (3.0%)	7 (4.8%)	0.332
Required total parental nutrition	1 (0.4%)	5 (3.4%)	0.021
Return to theatre	13 (4.8%)	8 (5.5%)	0.756
Readmission	16 (5.9%)	15 (10.3%)	0.103
Length of stay; day	5 (3–7 [1–47])	8 (6–11 [3–60])	<0.001
Highest CD grade			<0.001
No complication	159 (58.9%)	0 (0.0%)	
1	44 (16.3%)	0 (0.0%)	
2	49 (18.1%)	125 (86.2%)	
3	7 (2.6%)	8 (5.5%)	
4a	6 (2.6%)	8 (5.5%)	
4b	1 (0.4%)	3 (2.1%)	
5	4 (1.5%)	1 (0.7%)	
Highest CD grade excluding POI			0.016
No complication	159 (58.9%)	65 (44.8%)	
1	44 (16.3%)	22 (15.2%)	
2	49 (18.1%)	38 (26.2%)	
3	7 (2.6%)	8 (5.5%)	
4a	6 (2.2%)	8 (5.5%)	
4b	1 (0.4%)	3 (2.1%)	
5	4 (1.5%)	1 (0.7%)	
Complications			
Anastomotic leak[a]	13 (5.3%)	10 (7.4%)	0.400
Wound dehiscence/infection	16 (5.9%)	11 (7.6%)	0.513
Urinary retention	5 (1.9%)	4 (2.8%)	0.725
Urinary tract infection	3 (1.1%)	9 (6.2%)	0.005
Pneumonia/respiratory failure	22 (8.1%)	22 (15.2%)	0.027
Cardiac complication	4 (1.5%)	11 (7.6%)	0.004
DVT/VTE	1 (0.4%)	4 (2.8%)	0.053
High stoma output[b]	7 (11.9%)	5 (20.0%)	0.330
Sepsis	7 (2.6%)	5 (3.4%)	0.620
Electrolyte disturbance	29 (10.7%)	20 (13.8%)	0.358

Note: Values are median (IQR [range]), mean (SD) or number (proportion).

Abbreviations: CD, Clavien-Dindo grade; DVT/VTE, deep vein thrombosis or venous thromboembolism; ICU, intensive care unit; POI, postoperative ileus.

[a]$n = 247$ Non-POI patients had an anastomosis; $n = 135$ POI patients had an anastomosis.

[b]$n = 59$ Non-POI patients had a stoma; $n = 25$ POI patients had a stoma.

procedures, altering the risk of POI and its reported frequency. Of note, 40.3% of the patients in the current study experienced POI following reversal of ileostomy. Although the study aim was not to identify the incidence of POI following reversal of ileostomy, this is a considerably higher rate than the pooled estimate of 12.4% (95% CI: 9.2%–16.5%; $I_2 = 79\%$) by Garfinkle et al. [26]. The eight studies included in their review used a variety of POI definitions and did not use GI-2, thus highlighting that variations in definition can substantially alter the incidence of POI.

Variables previously shown to impact the development of POI such as ASA, malignancy status, stoma formation, preoperative haemoglobin and albumin levels, and intensive care unit admission did not reach significance in our cohort [5–7]. We suspect that this is the result of the wide range of definitions for POI used in previous studies. The validated GI-2 composite measure more uniformly diagnoses POI and provides better opportunities to compare study outcomes. The literature reported increase in total hospital cost of 48.4%–99.5% because of POI is larger than seen in our study

TABLE 3 Cost of inpatient stay

	Non-POI (n = 270)	POI (n = 145)	% difference	p-value
Total inpatient costs per patient	$29,821.70 ($20,410.18)	$37,689.87 ($21,586.73)	26.4% increase	<0.001
Total inpatient costs per patient excluding theatre, depreciation and nonclinical costs	$13,885.03 ($15,177.31)	$20,059.16 ($16,377.75)	44.5% increase	<0.001
Total inpatient costs per patient excluding CD grade >3[a]	$26,544.25 ($13,993.92)	$33,703.30 ($15,826.06)	27.0% increase	<0.001
Costing breakdown				
Medical staff	$1,774.26 ($2,168.99)	$2,549.24 ($1,943.36)	43.7% increase	<0.001
Nursing staff	$4,358.33 ($4,172.85)	$6,143.79 ($4,068.43)	41.0% increase	<0.001
Allied health staff	$206.59 ($577.99)	$470.15 ($1,143.10)	127.6% increase	0.002
Indirect salary costs	$2,540.99 ($1,959.57)	$3,301.39 ($2,257.06)	29.9% increase	<0.001
Critical care[b]	$13,986.17 ($10,802.94)	$12,056.36 ($7,801.33)	13.8% decrease	0.527
Theatre	$12,820.12 ($6,043.31)	$13,724.76 ($5,856.68)	7.1% increase	0.142
Imaging[c]	$786.68 ($1,129.06)	$809.88 ($837.29)	2.9% increase	0.890
Pathology[d]	$864.86 ($828.12)	$977.97 ($732.03)	13.1% increase	0.198
Pharmacy	$323.13 ($734.37)	$510.85 ($756.77)	58.1% increase	0.014
Supplies	$1,894.70 ($1,836.70)	$2,697.42 ($1,756.76)	42.4% increase	<0.001
Hospital services	$950.50 ($826.69)	$1,246.59 ($832.12)	31.2% increase	<0.001
Nonclinical	$588.75 ($487.78)	$788.43 ($464.97)	33.9% increase	<0.001
Depreciation	$2,464.76 ($1,502.81)	$2,998.56 ($1,557.07)	21.7% increase	<0.001

Note: Values are presented as mean (SD). Data presented in 2021 Australian dollars, adjusted for inflation.

Abbreviation: POI, postoperative ileus.

[a]n = 252 Non-POI patients after excluding CD grade >3; n = 125 POI after excluding CD grade >3.

[b]n = 17 Non-POI patients receiving critical care; n = 21 POI patients receiving critical care.

[c]n = 66 Non-POI patients receiving imaging; n = 77 POI patients receiving imaging.

[d]n = 227 Non-POI patients who had pathology; n = 129 POI patients who has pathology. p-value calculated for whole patient cohort.

(26.4%) [12–16]. This may be due to the other studies not using the CHEERS [17] guidelines, potentially leading to overestimation of costs. However, when excluding "fixed" costs of theatre, depreciation and nonclinical costs to ascertain the postoperative medical costs, we demonstrated a 44.5% increase in cost of inpatient stay, which is more in line with the literature. In comparison, Australia's public funding model is similar to that of New Zealand, where a single centre study reported a total cost increase of 71%, considerably larger than our results [16]. This is despite the similar rate of CD grade ≥3 (13.8%) of the current study compared to the 12% reported in their study [16]. When excluding CD grade >3 complications, to attempt to exclude other significant surgical complications, there was a 27% increase in total cost of inpatient stay for patients with POI. However, as POI often occurs in conjunction with other complications, this does not allow us to truly identify the cost of POI.

In the current study, the major cause of increased costs due to POI relates to the 3 days longer length of stay. This is in line with previous POI studies reporting an increased median length of stay of 4.9–7.5 days, significantly increasing medical and nursing staff costs [12–16]. Other factors increasing the cost of hospital stay include a higher demand for imaging to confirm the diagnosis or to investigate factors such as anastomotic leakage resulting in septic ileus or to diagnose POI-related complications such as pneumonia. Higher pharmacy costs were also noted, likely due to increased service requirement and greater opioid prescribing, which has previously been demonstrated [13]. It is well established, and reaffirmed in this study, that patients with POI are predisposed to other complications such as pneumonia, deep vein thrombosis and cardiac events [2, 10]. These POI-related complications have an additional considerable impact on cost. Although trying to isolate the costs of POI separately from other complications could be technically possible, it would be clinically irrelevant as these other complications coincide with POI. Costing data for other complications were therefore not adjusted. This allowed the current study to be a true representation of the overall clinical cost of POI.

In South Australia, for patients electing to use private hospital cover in a public hospital, gaps or excess charges are waived. We are therefore able to report the cost prior to reimbursement from

TABLE 4 Multivariate linear regression analysis on total cost of inpatient stay

Variable	*n* (%)	Cost	Univariate	Multivariate
Age ≥65			0.025	0.032
Yes	209 (50.4%)	$34,293.95 ($21,355.55)		
No	206 (49.6%)	$30,822.60 ($20,823.36)		
Gender			0.382	0.366
Female	169 (40.7%)	$31,873.34 ($21,542.68)		
Male	246 (59.3%)	$33,049.98 ($20,888.02)		
ASA >3			0.005	0.506
Yes	202 (48.7%)	$35,257.79 ($23,586.06)		
No	213 (51.3%)	$30,022.61 ($18,215.55)		
BMI >30			0.008	0.654
Yes	136 (32.8%)	$34,827.47 ($18,915.94)		
No	279 (67.2%)	$31,470.80 ($22,090.90)		
Smoking history			0.079	0.956
Yes	226 (54.5%)	$34,406.80 ($23,965.21)		
No	189 (45.5%)	$30,375.41 ($16,964.27)		
Undergone previous abdominal surgery			0.773	0.633
Yes	253 (61.0%)	$33,770.29 ($24,450.90)		
No	162 (39.0%)	$30,697.57 ($14,405.69)		
Conversion from laparoscopic to open procedure			<0.001	0.115
Yes	38 (16.1%)	$39,611.39 ($15,469.54)		
No	199 (83.9%)	$29,813.71 ($13,011.43)		
Stoma performed			0.001	<0.001
Yes	85 (20.5%)	$36,443.98 ($17,871.80)		
No	330 (79.5%)	$31,573.19 ($21,814.91)		
Operation type			<0.001	0.001
Large bowel	348 (83.9%)	$34,070.32 ($19,430.40)		
Reversal of ileostomy	67 (16.1%)	$24,918.94 ($27,211.30)		
Duration of theatre (median >150 min)			<0.001	<0.001
Yes	215 (51.8%)	$38,710.15 ($21,510.46)		
No	200 (48.2%)	$25,971.04 ($18,643.47)		
POI			<0.001	0.034
Yes	145 (34.9%)	$37,689.87 ($21,586.73)		
No	270 (65.1%)	$29,821.70 ($20,410.18)		
Total opioid use POD 1–4 (>median 150 MEQ)			<0.001	0.672
Yes	197 (48.4%)	$35,761.70 ($20,606.44)		
No	210 (51,6%)	$29,824.25 ($21,617.57)		
TAP catheters			0.013	0.581
Yes	141 (47.3%)	$32,573.31 ($15,484.46)		
No	157 (52.7%)	$30,380.62 ($22,636.61)		
CD grade (>3)			<0.001	0.002
Yes	38 (9.2%)	$68,811.22 ($35,094.29)		
No	377 (90.8%)	$28,917.94 ($14,990.53)		
ICU admission			<0.001	0.051
Yes	20 (4.8%)	$83,702.53 ($38,711.59)		

(Continues)

TABLE 4 (Continued)

Variable	*n* (%)	Cost	Univariate	Multivariate
No	395 (95.2%)	$29,981.87 ($16,057.59)		
Required total parental nutrition			<0.001	0.848
Yes	6 (1.4%)	$66,655.11 ($48,114.74)		
No	409 (98.6%)	$32,070.80 ($20,192.29)		
Urinary tract infection			0.028	0.126
Yes	12 (2.9%)	$41,754.25 ($19,159.66)		
No	403 (97.1%)	$32,297.37 ($21,155.72)		
Anastomotic leak			<0.001	0.280
Yes	23 (6.0%)	$66,127.23 ($33,792.25)		
No	359 (94.0%)	$30,891.49 ($18,897.74)		
Pneumonia/respiratory failure			<0.001	0.447
Yes	44 (10.6%)	$53,309.42 ($36,277.94)		
No	371 (89.4%)	$30,111.25 ($17,024.71)		
Cardiac complication			0.016	0.645
Yes	15 (3.3%)	$41,224.18 ($16,384.21)		
No	400 (96.4%)	$32,246.32 ($21,244.35)		
DVT/VTE			0.001	0.147
Yes	5 (1.2%)	$65,978.87 ($37,488.37)		
No	410 (98.8%)	$32,163.40 ($20,609.96)		
Length of stay (days)			<0.001	<0.001
≥6	227 (54.7%)	$41,255.42 ($24,856.28)		
<6	188 (45.3%)	$22,120.85 ($6,474.03)		

Note: Presented as mean (standard deviation) and number (frequency). Data presented in 2021 Australian dollars, adjusted for inflation.

Abbreviations: ASA, American Society of Anaesthesiologists physical status; BMI, body mass index; CD, Clavien-Dindo grade; DVT/VTE, deep vein thrombosis or venous thromboembolism; ICU, intensive care unit; MEQ, morphine equivalents; POD, postoperative day; POI, postoperative ileus; TAP, transversus abdominis plane.

private insurers from a single centre-public hospital analysis in South Australia. Given the differences between state and territories state/government reimbursement schemes across the country, the data from the current study are indicative of the cost of POI at a hospital level prior to reimbursement and could therefore be generalisable to hospitals throughout Australia.

In the univariate and multivariate linear regression analyses, older patients ($p = 0.032$), patients who had a stoma formed ($p < 0.001$), large bowel operations ($p = 0.001$), prolonged duration in theatre ($p < 0.001$), prolonged length of hospital stay ($p < 0.001$), CD grade ≥3 complications ($p = 0.002$) and POI ($p = 0.034$) were identified as independent predictors of an increased total cost of inpatient stay. These results confirm previous findings, that increased health care resource utilisation by factors such as age and stoma formation increase the total cost of inpatient stay [16, 27]. Also, increased duration in theatre has been shown to increase POI rates, and associated complications [5, 8, 28], due to difficulty in the operation, such as adhesions or extensive disease [8]. Despite CD grade ≥3 complications being predictive of increased total cost of admission, individual complications such as anastomotic leak ($p = 0.280$) or intensive care unit admission ($p = 0.051$) were not identified as predictors of an increased total cost of hospital stay. We speculate that these findings are a result of POI rarely occurring in isolation without other complications. Furthermore, length of stay is strongly predictive of increased hospital costs, likely owing to delayed discharge secondary to complications such as POI contributing to a loss of patient autonomy [11, 15, 16].

This study was limited by its retrospective design, with potential for selection or misclassification bias. To reduce this risk, patients were consecutively selected from the admission records, and complications were double checked via the prospectively collected Colorectal Unit morbidity and mortality audit in which GI-2 was used to classify POI. Highlighting a limitation of our definition of POI, 19 patients were discharged prior to achieving GI-2. These patients may have achieved GI-2 before postoperative day four, however this may have led to underestimation of POI. Furthermore, two patients who achieved GI-2 and were discharged on postoperative day 3, were shortly readmitted after discharge with POI requiring nasogastric decompression. Also, because of the time selected, there was differences in proportions of surgical procedures included, potential leading to recruitment bias. However, our cohort does represent the diverse elective work undertaken by our Colorectal Unit. Also, as this is a single-centre analysis, overall generalisability may be reduced. Despite the RAH being a major tertiary centre in South Australia, to

be able to map the full economic impact of POI in Australia, in future studies multiple sites with prospective data will be required.

CONCLUSION

This study shows that in an Australian institution, POI is associated with a significant increase in complications. POI was shown to be an independent predictor for increased total cost of hospital admission, along with age, stoma formation, prolonged length of stay and higher grade complications. Efforts aimed at reducing POI rates could diminish its morbidity and associated expenses, decreasing the burden on healthcare.

AUTHOR CONTRIBUTIONS

LT: conceptualisation; investigation; validation; analysis; writing original draft. MK: investigation; writing original draft: writing review and editing. SB: investigation; analysis; writing review and editing. HK: writing review and editing. MT: Supervision; writing review and editing. JM: Supervision; writing review and editing. TS: Supervision; writing review and editing.

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CONFLICT OF INTEREST

None.

DATA AVAILABILITY STATEMENT

Research data are not shared.

ETHICAL APPROVAL

The study was approved by the Central Adelaide Local Health Network Human Research Ethics Committee.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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