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Aggregate morbidity and mortality of defunctioning loop ileostomy fro formation to closure: a large population retrospective cohort analysis

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Abstract and Keywords

There is evidence that defunctioning loop ileostomies (DLIs) are associated with decreased risk of clinically significant anastomotic leaks, but at what cost? This population-based retrospective cohort study used administrative data to investigate differences in outcomes between patients undergoing low anterior resection with and without DLIs. We included all adult patients undergoing low anterior resection from 2002 to 2014 and identified outcomes within 30-days to 2-year of the index surgery. Outcomes included hospital readmission, reoperation, major complications, mortality, bleeding, and ileostomy reversal. DLIs were associated with significantly worse outcomes after low anterior resection, including increased risk of major complication, acute kidney injury, readmission, ventral hernia, bowel obstruction. There is certainly a role for DLIs to decrease risk of significant anastomotic leak requiring intervention and/or operation; however, DLIs are not benign entities. Based on the results of this study, it can be argued that selective utilization of DLIs should be recommended and further research into risk stratification and identification of patients who would benefit the most from DLIs are warranted.

Keywords: anterior resection, diverting loop ileostomy, anastomotic leak, general surgery

Table of Contents

List of Tables

List of Figures

List of Appendices

List of Abbreviations

1) AL: Anastomotic leak
2) DLI: Defunctioning loop ileostomy
3) LAR: Low anterior resection
4) TME: Total mesorectal excision
5) QoL: Quality of life
6) ICES: Institute of Clinical and Evaluative Sciences
7) CIHI: Canadian Institute for Health Information database
8) RPDB: Registered Persons Database
9) DAD: Discharge Abstract Database
10) SDS: Same Day Surgery database
11) NACRS: National Ambulatory Care Reporting System
12) OHIP: Ontario Health Insurance Plan database
13) OCR: Ontario Cancer Registry
14) ICD-10-CA: International Classification of Diseases, Tenth Revision, Canada
15) CCI: Canadian Classification of health Interventions
16) LHIN: Local Health Integration Network
17) ACG: Adjusted Clinical Groups
18) RUB: Resource Utilization Bands
19) ASA: American Society of Anesthesiologist
20) SD: Standardized differences
21) OR: Odds ratio
22) CI: Confidence interval

23) STD: Standard deviation

24) IQR: Interquartile ratio

25) RCT: Randomized controlled trials

26) AKI: Acute kidney injury

27) SCFA: Short-chain fatty acids

28) RR: Relative risk

29) NSQIP: National Surgery Quality Improvement Project

30) GI: Ghost ileostomy

Chapter I: Introduction

1.1 A review of current literature

The most serious risk of a colorectal anastomosis is an anastomotic leak (AL). Clinical correlates of ALs include local or systemic sepsis, percutaneous intervention, reoperation, increased hospital length of stay, and increased risk of mortality. Defunctioning loop ileostomy (DLI) was introduced as a method to mitigate the clinical sequelae of AL [1]. A number of studies have shown that although DLI does not decrease the incidence of AL, it does decrease the severity of complications associated with ALs [2-5]. However, DLIs are not without risk and controversy still exists on when they should be utilized. The purpose of this review is to objectively examine the benefits and risks of defunctioning loop ileostomies based on a comprehensive review of current literature.

1.2 Indications for defunctioning loop ileostomy

Defunctioning loop ileostomies are most commonly fashioned after colorectal anastomosis for rectal cancer. Studies evaluating risk factors for ALs have shown that a low or ultra-low colorectal anastomosis is associated with significantly higher risk for leaks [5-7]. Other risk factors include male sex, age > 70 years, malnutrition, smoking, corticosteroid use, diabetes, and pre-operative radiation therapy [3,7,8,9]. As surgical techniques progressed throughout the years, the introduction of stapling devices allowed surgeons to fashion much lower colorectal anastomoses in hopes of preserving bowel continuity. Thus, there was an initial increase in ALs after low anterior resection (LAR) [10]. DLIs were introduced as a mechanism to divert the fecal stream from the newly formed anastomosis. The function is two-fold: first, if an AL occurs, the

DLI will decrease septic complications from the leak by significantly decreasing fecal leakage and contamination; second, by diverting the fecal stream, there is less mechanical irritation on the new anastomosis [10].

Rectal cancer is not the only indication for a DLI. Acute complicated diverticulitis may require emergency sigmoidectomy, primary anastomosis and DLI. Traditionally, the more common procedure would have been the Hartmann's procedure with sigmoidectomy, end colostomy, and closure of rectal stump but more and more surgeons are moving onto performing primary colorectal anastomosis, with or without a DLI. Other indications for partial colectomy and colorectal anastomosis that may require a protective DLI include: sigmoid volvulus, Crohn's colitis, large polyps unable to be removed endoscopically, and traumatic colonic injury [8]. Finally, a DLI is often constructed to protect the ileal pouch anal anastomosis after a restorative proctocolectomy for ulcerative colitis [7,11,12].

1.3 Anastomotic leak

Anastomotic leak is one of the most feared complications after primary colorectal anastomosis. Currently, there is no consensus on the definition of AL. A systematic review conducted by Bruce et al. discovered 56 different definitions of AL [13]. The International Study Group of Rectal Cancer classifies AL into AL requiring no active intervention (class A), AL requiring intervention but without re-laparotomy (class B), and AL requiring re-laparotomy (class C) [14]. Most surgeons would consider Class B and C AL to be clinically significant. The rate of AL after colorectal anastomosis ranges from 2-39% and may depend on the height of the anastomosis [10,15]. Estimated mortality from symptomatic AL ranges from 6 – 22% [2,10]. AL also leads to

reoperation in 1.5 – 2.7 % of patients and is associated with increased hospital length of stay, increased hospital costs, and worse oncologic outcomes [16-18]. Mirnezami et al. conducted a systematic review and meta-analysis of studies that assessed oncologic outcomes of colorectal cancer patients with AL. The authors reported that patients with ALs had significantly higher odds of local recurrence (OR 2.05, $p = 0.0001$) and significantly reduced odds of cancer specific survival (OR 1.64, $p = 0.0001$) [19]. A non-significant increase in distant recurrence was also reported in all seven studies that investigated this outcome [19]. Lu et al. conducted a similar but more recent meta-analysis that also demonstrated greater local cancer recurrence after AL (OR 1.61, $p < 0.001$) but no statistically significant difference in distant recurrence [18].

Fashioning a DLI has become the standard of care for colorectal anastomoses, largely because a few studies have demonstrated significant benefit in overall morbidity [3,8,11,20]. Matthiessen et al. conducted a randomized, multicenter trial analyzing the effect of DLIs in rectal cancer patients undergoing LAR. One specific inclusion criteria was that the anastomosis had to be ≤ 7 cm from the anal verge. The definition of AL used in this study was clinical: peritonitis caused by leakage from any staple line, rectovaginal fistula, or pelvic abscess [20]. The authors found that patients with DLIs had significantly fewer ALs, with a rate of 10.3% versus 28.0% ($p < 0.001$) [20]. Furthermore, the DLI group had a significantly lower reoperation rate (8.6% vs. 25.4%, $p < 0.001$) [20]. Mrak et al. conducted a similar study of rectal cancer patients undergoing low anterior resection with total mesorectal excision (TME) [3]. Patients were randomized to receive a DLI or no DLI. Patients in the DLI group had a lower AL rate of 5.8% versus 16.3% ($p = 0.0441$) and were also less likely to need surgical intervention for their leaks (20% versus 92.3%; $p = 0.006$) [3]. A number of retrospective observational studies have also

demonstrated that DLIs are associated with decreased risk of AL, although not all leaks were defined as symptomatic [8,11,21].

Contrarily, numerous studies have also failed to show the benefits of DLIs [2,9,22-24, 27]. Gastinger et al. conducted a multi-center prospective observational study looking at early outcome after LAR in patients with and without a protective stoma. The overall AL rate was similar in both groups: 14.5% for those with a stoma versus 14.2% for those without ($p = 0.806$) [2]. Patients without a protective stoma did have significantly higher reoperation rates (10.1% vs. 3.6%, $p < 0.001$) [2]. However, the group with a protective stoma had significantly higher overall morbidity (39.7% vs. 34.4%, $p = 0.007$) [2]. Similarly, Maroney et al. compared the overall 6-month complication rate between patients who underwent LAR with or without DLI and found that the stoma group had significantly higher complication rates (61% vs. 38%, $p = 0.02$) [23]. Inhát et al. found a 53.8% stoma related complication rate in their retrospective observational study [25], whereas Marusch et al. discovered significantly higher wound infection rates in patients with diversion stomas (7.4% vs. 2.7%, $p = 0.016$) [22]. There is no mortality benefit from DLIs [22,25-26].

Platell et al. conducted a prospective observational study on patients undergoing LAR or ultra-low anterior resection with DLI. In their cohort of 233 patients, 16 patients were diagnosed with AL (7%); seven of those patients were asymptomatic and only nine required interventions [27]. Ultimately, only 2 (0.9%) required reoperation. The authors concluded that > 90% of their patient population did not benefit from DLIs and that closure of the ileostomy added 7 days to

overall inpatient length of stay [27]. Similarly, Kanellos et al. recommended against routine DLI with LAR based on their retrospective study that demonstrated a low rate of AL [28].

1.4 Complications of defunctioning loop ileostomies

There is evidence that DLIs may decrease AL, pelvic sepsis, and rate of reoperation, but DLIs themselves are associated with longer hospital length of stay and overall morbidity. In this section, we will review specific complications associated with DLIs. See Table 1 for a summary of current literature.

1.4.1 Dehydration and acute renal failure

A DLI by definition bypasses the colon entirely. The effluent released from the ileostomy has significantly higher water content than normal stool. Normal ileostomy output volume ranges from 500-1000 mL/day; however, patients can and often have increased ostomy output of up to 2500 mL/day [29]. Such high losses are difficult for patients to replenish and manage and patients often present back to the hospital with acute dehydration and even acute renal failure. Åkesson et al. conducted a retrospective review looking at the morbidity of DLIs and found that 32% of patients required hospital readmission secondary to stoma related complications. Further, 29% of patients had at least one episode of dehydration of greater than 2000mL ostomy output, of which half required hospital readmission for intravenous fluid resuscitation and two patients needed admission to the intensive care unit [29]. Some research has also suggested that elderly patients are more prone to dehydration. For example, Paquette et al. conducted a retrospective cohort study that demonstrated age > 50 was associated with hospital readmission secondary to dehydration [30]. In 2013, Jafari et al. conducted a large population-based retrospective cohort

study assessing the morbidity of DLIs. Compared to the patients undergoing LAR without DLI, patients who had DLIs had significantly higher rates of progressive renal insufficiency (2.1% vs 0.8% $p < 0.05$) [31] and a 2.37-fold increase in risk of acute renal failure (95% CI 1.21 – 4.6, $p = 0.01$) [31]. Diverted patients also had significantly higher readmission rates (20.3% vs 11%, $p < 0.05$) [31]. Messaris et al. demonstrated a 16.9% all-cause readmission rate after ileostomy creation, of which almost half were due to dehydration (7.3%) [32].

1.4.2 Stoma related complications

Having a DLI itself is associated with a number of complications. Some of these include stoma retraction, prolapsing ostomy requiring reoperation, stenosis causing obstruction, bleeding, stoma necrosis, parastomal hernia, and fistula formation [23,30-31,33-37]. In a retrospective cohort analysis of patients with DLIs, Åkesson et al. reported a 32% hospital readmission rate due to stoma related complications. The majority of these readmissions (59%) were related to minor problems such as skin irritation, leakage from dressing, and wound infections. However, patients were also readmitted due to more serious complications, such as dehydration (29%), obstruction (14%), parastomal hernia (14%), and gastrointestinal bleed (6%) [30]. Other retrospective cohort studies have revealed similar rates of complications [31,33-37]. Patient associated morbidities that may significantly decrease quality of life have also been reported, including leakage from the ostomy appliance, skin excoriation, soiling and odor, and frequent night time emptying requirements [33].

1.4.3 Morbidity associated with ileostomy reversal

The reversal of a defunctioning loop ileostomy is a separate operation associated with its own risks. An ileostomy reversal requires resection of the ostomy and another bowel anastomosis. In 2009, Chow et al. conducted a systematic review of 48 studies that analyzed morbidity associated with ostomy reversal [7]. Complications occurred in 823 out of 4765 patients giving a morbidity rate of 17.3%. The most common bowel related complication was small bowel obstruction (7.2%), with a third of these patients requiring surgical intervention [7]. Sixty patients suffered from anastomotic leaks (1.4%). Wound infection was the most common non-bowel related complication at 5%. Sixty-eight patients (1.3%) developed incisional hernias through the stoma site. The Mortality rate was 0.4%. This large series systematic review demonstrated that ileostomy reversal is not benign and is associated with a low, albeit real mortality rate. Other retrospective cohort analyses, the most recent one being from 2016, have also shown similar complications following ileostomy reversal and have also reported findings of post-operative ileus, urinary retention, abscess formation, enterocutaneous fistula, and deep venous thrombosis [34,37,38,39].

1.4.4 Unwanted permanent ostomy

To meet criteria for an ileostomy reversal, patients must be physiologically fit to undergo a second elective surgery and their colo-rectal anastomosis must be completely healed. A portion of patients will end up with an unwanted permanent ostomy if they do not meet these criteria. A number of retrospective cohort studies have analyzed the rate of permanent ileostomies after planned temporary ostomy. The rate ranged between 3%-25% [36,40-44]. In 2016, Kim et al. published a retrospective review assessing the rate of permanent stoma after rectal cancer

surgery [40]. Of the 673 patients that were identified as having a temporary ileostomy, 9.5% of these patients ended up with a permanent stoma. Within the group of patients with a permanent stoma, 36% never had their temporary ileostomy reversed and 64% ended up with a new permanent ostomy after initial ileostomy reversal [40]. Of the patients who never had their ileostomy reversed, the main reason was due to systemic metastatic disease, but other reasons included intractable anastomosis stricture, poor general condition, and patient refusal. Interestingly, a significant portion of patients with permanent ostomies are secondary ostomies due to complications after ileostomy reversal. These patients had loop ileostomies or colostomies. Reasons listed for a secondary permanent stoma included local recurrence, uncontrolled pelvic abscess, unsatisfactory anorectal function, and intractable anastomosis stricture [40]. Not only is a permanent ostomy associated with the risks of an ostomy as reported above, it can also significantly affect patients' quality of life.

Table 1. Summary of retrospective and prospective studies analyzing morbidity of DLIs

Author (year)	N	Overall morbidity	SBO	AKI	Parastomal hernia	Permanent stoma
Åkesson (2012)	92	-	13%	27%	13%	11%
Chun (2012)	123	64.2%	2.4%	13%	4.8%	-
Gessler (2012)	262	-	3%	18%	7%	23%
Hallböök (2002)	222	-	18.5%	-	18.5%	-
Hayden (2013)	154	-	-	20%	-	-
Holmgren (2017)	316	9%	-	-	-	24%
Ihnát (2016)	151	53.8%	3.8%	-	-	-
Jayarajah (2016)	192	34.2%	-	-	-	-
Kim (2016)	673	-	-	-	-	9.5%
Lindgren (2011)	116	-	-	-	-	19%
Man (2016)	213	16.4%	-	-	-	-
Pan (2013)	296	-	-	-	-	17.2%
Paquette (2013)	201	-	-	17%	-	-
Perez (2006)	93	17.2%	11.8%		-	-
Phatak (2008)	294	-	-	11%	-	-
Sier (2015)	485	-	-	-	-	26%
Waterland (2015)	170	-	-	-	-	25%

1.4.5 Quality of life

Although not extensively studied, the presence of an ostomy, even a temporary one, can significantly affect quality of life (QoL). A lot of the evidence stems from direct patient encounters. Often, follow up patient encounters after index surgery involves discussions about when the ileostomy can be reversed. To date, there have only been a few longitudinal observational studies that have investigated QoL in patients with a temporary ileostomy, both

while they have the ileostomy and after reversal. In 2008, Tsunoda et al. conducted one of the earliest prospective longitudinal studies looking at patient QoL after low anterior resection with DLI [41]. The authors followed 22 patients and assessed different aspects of their QoL with the European Organization for Research and Treatment of Cancer (EORTC) QLQ – C30 and QLQ – CR38 questionnaires. Patients filled out the questionnaire at four distinct time points: before surgery, 2 months after resection (before ileostomy reversal), 5 months after resection, and 8 months after resection. One benefit that the authors found was that patients' global QoL scores were significantly higher after the index surgery as compared to the preoperative score, indicating that surgical resection of the tumor improved their overall QoL. Similarly, both future perspective and social function scores improved after surgery. However, patients that had an ileostomy had significantly lower physical function scores and role function scores at 2 months as compared to before surgery ($p < 0.05$) [41]. A similar study conducted in 2016 with a much larger patient population (n=120) identified similar results, demonstrating significantly lower role functioning, social functioning, and physical functioning after surgery and before ileostomy reversal [42].

O'Leary et al. conducted a prospective longitudinal study that identified patients' main concerns before and after low anterior resection with DLI [43]. Before surgery, patients were worried about the surgery itself and cancer. Twelve weeks after resection, patients' most frequent concerns were stoma closure, cancer recurrence, and continued health. Six weeks after ileostomy closure, their principle concern was bowel function [43]. In 2011, Neuman et al. identified more specific patient concerns regarding the ostomy [44]. In this study, they identified a significant decrease in body image that continued even after stoma reversal ($p = 0.03$). Of the patients with

identified stoma related difficulties, 53% reported issues with sexual activity, 39% with leakage, 34% with discomfort in clothing, 32% with concerns regarding privacy to empty the pouch, and 31% reported feeling unattractive [44]. One important aspect that multiple studies discovered was that there was a persistent decrease in QoL even after ileostomy reversal, often associated with changes in bowel function and diminished body image [43-45]. In 2010, Taylor & Morgan published a review on QoL following reversal of temporary stoma and identified nine studies that assessed QoL outcomes after stoma reversal [45]. In this review, bowel function was identified as the principle concern of patients six weeks after ostomy closure, with frequency and urgency of defecation and fecal incontinence being the main symptoms. The functional bowel symptoms also had an impact on patients' psychosocial health, chiefly related to altered body image and attractiveness. Unfortunately, Camilleri-Brennan & Steel noted that there was no improvement in body image even after stoma reversal [46].

1.5 Summary

The utilization of defunctioning loop ileostomies after low anterior resection for rectal cancers has increased significantly in the past few years. There is evidence that DLIs are associated with decreased risk of clinically significant anastomotic leaks, but at what cost? DLIs are also associated with significant morbidity, from the time of formation to after closure. Furthermore, DLIs are associated with deteriorated quality of life. Surgeons need to consider a more selective utilization of DLIs in patients at high risk for anastomotic leak and explore alternative approaches to reduce the rate and impact of ALs.

1.6 Study objective

The clinical controversy and equipoise are the basis of this research project. The purpose of this project is to identify aggregate morbidity associated with defunctioning loop ileostomy. The main objective of this study is to identify and analyze all morbidity associated with a defunctioning loop ileostomy from the onset of its creation to after its reversal, compared to patients without a defunctioning loop ileostomy. Perioperative outcomes of interest include: 30-day hospital readmission, 30-day reoperation, 30-day major complications, 30-day mortality, 90-day mortality, 1-year mortality, bleeding, and hospital length of stay during the index admission. Other outcomes of interest include deep space infection, bowel obstruction, hernia, acute kidney injury, and permanent ostomy.

Chapter II: Project design, methodology, and statistics

2.1 Study design

Because of the clinical equipoise identified in both the scientific literature and in clinical practice, the purpose of this project was to investigate the morbidity associated with defunctioning loop ileostomies (DLIs) within a large, population-based retrospective cohort.

The Institute of Clinical and Evaluative Sciences (ICES) is a large, not-for-profit, research institute that has access to a number of Ontario's health-related administrative databases. Ontario is one of the most populous provinces of Canada with 14.3 million residents. The healthcare for these patients is provided by the provincial government in a publicly funded single payer system. The data was obtained from the following databases: Canadian Institute for Health Information database (CIHI); Registered Persons Database (RPDB); Discharge Abstract Database (DAD); Same Day Surgery Database (SDS); National Ambulatory Care Reporting System (NACRS); Ontario Health Insurance Plan (OHIP) database; Ontario Cancer Registry (OCR); and the ICES Physician Database. All diagnoses were documented and coded using the International Classification of Diseases and Related Health Problems, Tenth Revision, Canada (ICD-10-CA). Procedural codes were also obtained from physician billings to OHIP and from Canadian Classification of health Interventions (CCI) codes within CIHI.

2.2 Cohort identification

The most common indication for a DLI is a low anterior resection (LAR). In an effort to decrease heterogeneity of the patient cohort, the cohort included adult patients > 18 years of age undergoing elective anterior resection with or without a DLI from April 1, 2002 – March 31,

2014. The year 2002 was chosen as the start date because ICD codes were changed from version 9 to version 10 in 2002 in Canada. The end date was chosen to allow enough time for observation after index surgery.

Anterior resections were identified using both OHIP billing codes (S213 or S171) and CCI procedure codes (Appendix A). Patients were defined as have a DLI if a billing code for ileostomy (S149) was also billed on the same date as the anterior resection. Patients were excluded if their surgery was only recorded in OHIP but not CIHI, their age or sex was unknown, they were a non-Ontario resident, they were < 18 years of age, they had pre-existing renal disease, or if they had a previous anterior resection or DLI. Rectal cancer patients were identified using the Ontario Cancer Registry. Patients with missing data were excluded from the cohort.

Formal sample size calculation was not done for this study for a number of reasons. First, the patient cohort was expected to be quite large given that it is a population based retrospective analysis. The inclusion criteria for the patient cohort was set quite broadly to capture a wide range of patients. Second, there were numerous outcomes of interest, some were composite outcomes including 12 variables and no one variable was considered the main outcome of interest.

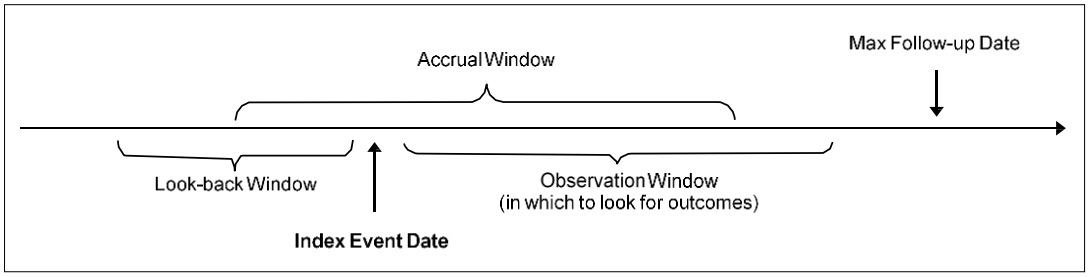
2.3 Data collection & timeline

The index event was defined as date of LAR with or without DLI. A two-year look back window was used to assess for patient comorbidities and a five-year look back window was used to

determine history of renal disease. The observation window for outcomes and ileostomy reversal closed one and two years after the index date, respectively (see Figure 1 for a graphical depiction of the data collection timeline).

For patients with a DLI, a second index event was defined as the date of ileostomy reversal (Appendix A). A 180-day observation window was used to look for complications associated with the ileostomy reversal.

Figure 1. Accrual, lookback, observation, and follow-up window diagram



2.4 Baseline variables

Important patient baseline variables were collected. These include patient age, sex, income quintile, patient Local Health Integration Network (LHIN), rurality (urban vs. rural), co-morbidity using John's Hopkins Adjusted Clinical Groups Resource Utilization Bands (ACG-RUB) system, history of rectal cancer, history of colon cancer, stage of rectal cancer, and history of radiation or chemotherapy (Appendix B & C) [47]. The ACG-RUB system captures all morbidities for which a patient receives care during a defined period. The ACGs can be collapsed into six RUBs on the basis of expected use of health care resources. In this present study, we used the CIHI-DAD, CIHI-SDS, CIHI-NACRS, and OHIP databases to calculate RUBS, which were summarized as a 3-point ordinal variable: 1 = low (RUB 0-3), 2 = moderate

(RUB = 4), and 3 = high (RUB =5). Procedural, institutional and surgeon related variables were also collected, including open versus laparoscopic surgical approach, American Society of Anesthesiologist (ASA) classification for medical status, institution teaching status (academic versus community), surgeon age, surgeon annual anterior resection volume, and fiscal year (Appendix B & C).

2.5 Defining outcomes of interests

Each outcome of interest was associated with an observation window (Appendix D) and one or more codes (Appendix E). All outcomes of interest were defined *a priori*. In this study, major complication was a composite outcome that captured the following conditions: sepsis, myocardial infarction, stroke, pulmonary embolism and deep vein thrombosis, pneumonia, acute renal failure and renal failure requiring dialysis, atrial fibrillation/flutter, blood transfusion, cardiac/respiratory arrest, coma, shock, and ventilator use > 48 hrs (Appendix D). Major complications were assessed within 30-days of the index surgery date as well as within 30-days of the ileostomy reversal date. Acute kidney injury was defined as acute renal failure requiring hospitalization within 180 days of index surgery. The codes utilized for acute kidney injury were a combination of codes, some of which were validated ICD-10 codes for acute kidney injury and other were from the KDT variable library [48]. A bleeding complication was defined as bleeding severe enough to require at least one blood transfusion within 30 days of index surgery. A deep space infection was defined using a combination of wound infection codes plus drainage intervention codes; thus, only infections severe enough to require a drain were considered. Patients without an ileostomy reversal within two years after index surgery were considered to have a permanent ostomy.

Hospital length of stay after index surgery as well as number of days spent in hospital within 30 days of index surgery and 1 year of index surgery were recorded (Appendix D).

Anastomotic leak was an important outcome of interest of ours. However, there is no single code for anastomotic leak in ICD-10. Attempts were made at using surrogate codes for anastomotic leak such as combining codes for deep space infection with percutaneous drainage, however, the numbers identified were discordant with clinical reality and expectation. It was thought that the numbers were over-estimating rates of anastomotic leak and deemed inaccurate.

2.6 Statistics and analysis

Once the cohort was identified, patients were separated into two major subgroups: patients with rectal cancer and patients without. All analyses were conducted separately for the subgroups.

Baseline differences between patients with and without DLI were evaluated using standardized differences (SD), Calculated as the difference in proportions divided by the standard error. A SD > 0.10 can be interpreted as a potentially meaningful between group difference [49]. SDs often provide a better indication of between group differences in large observational studies, where even the slightest difference can yield a significant result due to the impact of sample size on significance testing. Trends across the study period were assessed using the Cochran-Armitage test for trend.

Unadjusted logistic regression was used to estimate the effect of DLI on all projected outcomes. Adjusted logistic regression was also used to control for the following variables: patient age and sex, expected resource utilization, history of chemotherapy or radiotherapy, ASA classification (ASA > 2), institution teaching status, surgeon annual volume, and fiscal year of the procedure. The variables chosen for adjustment were chosen *a priori* and were based on clinical experience knowing that these factors would contribute and confound a number of the outcomes of interest. Adjusted models used a generalized estimating equation approach with an exchangeable correlation structure to account for the clustering of patients within physicians and institutions. Outcomes are reported as odds ratios and 95% confidence intervals. Outcomes such as 30- and 90-day mortality could not be investigated in adjusted models due to the small number of events. The linearity of continuous predictors was assessed using restricted cubic splines [50]. Annual surgeon volume demonstrated non-linearity and was dichotomized at the 50th percentile prior to modeling.

For all analyses, reported *p*-values are from 2-tailed tests where a value of $p < 0.05$ was considered statistically significant. All analyses were performed using SAS EG version 7.1 (SAS Institute, Cary, NC, USA).

Part III: Results

3.1 Baseline characteristics

The initial search identified 32,200 patients from 2002-2014 that met the inclusion criteria. Sixty-five patients were excluded for being less than 18 years old. Four thousand and 424 patients were excluded because they did not have a matching operation of low anterior resection in CIHI records. Patients with previous LAR and/or ileostomies and patients with a history of renal failure were also excluded, leaving a total of 25,491 patients in the overall cohort. Of the overall cohort, 18% (4,658) of patients had a concomitant DLI with their LAR.

Patients were divided into two sub-groups on the basis of whether or not they had rectal cancer. The rectal cancer subgroup consisted of a total of 6,146 patients and 2,690 (43.8%) of these had a DLI. Patient characteristics for the rectal cancer subgroup are reported in Table 2. Stage III cancer was most prominent within this group (39.4%), followed by Stage I (25.8%) and Stage II (23.2%). Within each cancer stage, approximately half of the patients had a DLI (Table 3). Patients in the DLI group were more likely to have a history of radiation therapy (50% vs. 14.9%, SD = 0.81) and chemotherapy (33.8% vs 14.9%, SD = 0.59) and were also more likely to have their procedure performed in a teaching institution (41.3% vs. 26.8%, SD = 0.31).

Table 2. Baseline characteristics for rectal cancer subgroup

Variable	Overall (n = 6,146)	No ileostomy (n = 3,446)	Ileostomy (n = 2,700)	SD	*p*-value
Patient age†	65.0 (57.0-73.0)	67.0 (58.0-75.0)	64.0 (56.0-72.0)	0.21	<.001
Patient sex (Female)	2,243 (36.5%)	1,351 (39.2%)	892 (33.0%)	0.13	<.001
Rural residence	935 (15.2%)	513 (14.9%)	422 (15.6%)	0.02	0.421
Income*					
Quintile 1	1,068 (17.4%)	599 (17.4%)	469 (17.4%)	0.00	0.074
Quintile 2	1,251 (20.4%)	715 (20.7%)	536 (19.9%)	0.02	0.074
Quintile 3	1,200 (19.5%)	713 (20.7%)	487 (18.0%)	0.07	0.074
Quintile 4	1,307 (21.3%)	712 (20.7%)	595 (22.0%)	0.03	0.074
Quintile 5	1,301 (21.2%)	697 (20.2%)	604 (22.4%)	0.05	0.074
Resource Utilization					
Low	2,004 (32.6%)	1,136 (33.0%)	868 (32.1%)	0.02	0.921
Moderate	2,377 (38.7%)	1,305 (37.9%)	1,072 (39.7%)	0.04	0.921
High	1,765 (28.7%)	1,005 (29.2%)	760 (28.1%)	0.02	0.921
ASA 3+	3,528 (57.4%)	1,869 (54.2%)	1,659 (61.4%)	0.15	<.001
Approach	634 (10.3%)	345 (10.0%)	289 (10.7%)	0.02	0.376
Converted	273 (4.4%)	155 (4.5%)	118 (4.4%)	0.01	0.81
Colon cancer	122 (2.0%)	77 (2.2%)	45 (1.7%)	0.04	0.113
Rectosigmoid cancer	<=5	<=5	<=5	0.03	0.211
Radiotherapy	1,860 (30.3%)	509 (14.8%)	1,351 (50.0%)	0.81	<.001
Chemotherapy	1,261 (20.5%)	349 (10.1%)	912 (33.8%)	0.60	<.001
After hours procedure	168 (2.7%)	129 (3.7%)	39 (1.4%)	0.15	<.001
Teaching status	2,037 (33.1%)	923 (26.8%)	1,114 (41.3%)	0.31	<.001
Surgeon age†	45.0 (39.0-52.0)	46.0 (39.0-53.0)	44.0 (39.0-51.0)	0.15	<.001
Annual volume†	11.0 (6.0-18.0)	10.0 (6.0-16.0)	13.0 (7.0-21.0)	0.29	<.001
Cancer Stage‡					
Stage unknown	174 (4.6%)	87 (4.9%)	87 (4.3%)	0.03	<.001
Stage 0	16 (0.4%)	9 (0.5%)	7 (0.3%)	0.02	<.001
Stage 1	986 (25.8%)	517 (29.0%)	469 (23.0%)	0.14	<.001
Stage 2	887 (23.2%)	392 (22.0%)	495 (24.3%)	0.05	<.001
Stage 3	1,504 (39.4%)	638 (35.8%)	866 (42.5%)	0.14	<.001
Stage 4	251 (6.6%)	138 (7.7%)	113 (5.5%)	0.09	<.001

*Missing data for 19 patients; †Median (IQR); ‡Restricted to patients with a cancer diagnosis after April 1, 2007 (total n=3818, exposed n=2030); SD = Standardized Difference.

Table 3. Stages of rectal cancer

Cancer Stage	Overall	Ileostomy	%
Stage 0	16 (0.4%)	7	43.8
Stage 1	986 (25.8%)	469	47.6
Stage 2	887 (23.2%)	495	55.8
Stage 3	1504 (39.4%)	866	57.6
Stage 4	251 (6.6%)	113	45.0
Stage NA	174 (4.6%)	87	50.0

The subgroup of patients without rectal cancer included patients with colon cancer, rectosigmoid cancer, and patients who underwent a LAR for other indications (Table 4). There was a total of 19,345 patients in this subgroup, of which only 1,943 (10%) received a DLI. Of the patients with colon cancer, only 4.5% had a DLI, whereas 17.3% of patients that had rectosigmoid cancers had a DLI. Similar to the rectal cancer subgroup, patients in this subgroup who received a DLI were also more likely to be treated in a teaching hospital and to have a history of radiation and chemotherapy (Table 4).

3.2 Trend of defunctioning loop ileostomies

When assessing the proportion of patients who underwent anterior resection with DLI, there is a clear upward trend over time. In 2002, only 8.5% of patients had a DLI compared to 25.5% in 2013 (Figure 2). This increase is more pronounced in the rectal cancer group, with an increase from 19.1% in 2002 to 55.8% in 2013 ($p < 0.0001$) (Table 5).

Table 4. Baseline characteristics for non-rectal cancer subgroup

Variable	Overall (n = 19,345)	No ileostomy (n = 17,387)	Ileostomy (n = 1,958)	SD	*p*-value
Patient age†	65.0 (55.0-74.0)	65.0 (55.0-74.0)	64.0 (54.0-73.0)	0.11	<.001
Patient sex (Female)	9,431 (48.8%)	8,551 (49.2%)	880 (44.9%)	0.08	<.001
Rural residence*	2,640 (13.6%)	2,317 (13.3%)	323 (16.5%)	0.09	<.001
Income*					
Quintle 1	3,489 (18.0%)	3,084 (17.7%)	405 (20.7%)	0.07	<.001
Quintle 2	3,876 (20.0%)	3,484 (20.0%)	392 (20.0%)	0.00	<.001
Quintle 3	3,861 (20.0%)	3,464 (19.9%)	397 (20.3%)	0.01	<.001
Quintle 4	4,051 (20.9%)	3,648 (21.0%)	403 (20.6%)	0.01	<.001
Quintle 5	4,014 (20.7%)	3,657 (21.0%)	357 (18.2%)	0.07	<.001
Resource Utilization					
Low	6,654 (34.4%)	6,063 (34.9%)	591 (30.2%)	0.10	<.001
Moderate	7,141 (36.9%)	6,412 (36.9%)	729 (37.2%)	0.01	<.001
High	5,550 (28.7%)	4,912 (28.3%)	638 (32.6%)	0.09	<.001
ASA 3+	10,484 (54.2%)	9,261 (53.3%)	1,223 (62.5%)	0.19	<.001
Approach	1,551 (8.0%)	1,393 (8.0%)	158 (8.1%)	0.00	0.929
Converted	1,222 (6.3%)	1,100 (6.3%)	122 (6.2%)	0.00	0.869
Colon cancer	6,562 (33.9%)	6,261 (36.0%)	301 (15.4%)	0.49	<.001
Rectosigmoid cancer	4,050 (20.9%)	3,349 (19.3%)	701 (35.8%)	0.38	<.001
Radiotherapy	483 (2.5%)	199 (1.1%)	284 (14.5%)	0.51	<.001
Chemotherapy	479 (2.5%)	261 (1.5%)	218 (11.1%)	0.40	<.001
After hours procedure	1,490 (7.7%)	1,318 (7.6%)	172 (8.8%)	0.04	0.058
Teaching status	4,650 (24.0%)	3,939 (22.7%)	711 (36.3%)	0.30	<.001
Surgeon age†	45.0 (39.0-53.0)	45.0 (39.0-53.0)	45.0 (39.0-52.0)	0.05	0.027
Annual volume†	10.0 (6.0-16.0)	10.0 (6.0-16.0)	10.0 (5.0-16.0)	0.05	0.02

*Rural and Neighbourhood income missing data for 2 and 54 patients, respectively; SD = Standardized Difference.

Table 5. Ileostomy timeline and trend

Year	No Rectal Cancer			Rectal Cancer		
	Total n	Ileostomy n	Ileostomy %	Total n	Ileostomy n	Ileostomy %
2002	1562	94	6.02%	392	75	19.13%
2003	1753	106	6.05%	453	117	25.83%
2004	1793	118	6.58%	454	129	28.41%
2005	1775	125	7.04%	548	168	30.66%
2006	1503	126	8.38%	481	174	36.17%
2007	1450	135	9.31%	452	217	48.01%
2008	1498	149	9.95%	504	246	48.81%
2009	1594	185	11.61%	601	306	50.92%
2010	1598	205	12.83%	553	307	55.52%
2011	1646	254	15.43%	564	325	57.62%
2012	1641	241	14.69%	576	319	55.38%
2013	1532	220	14.36%	568	317	55.81%
Overall	19345	1958	10.12%	6146	2700	43.93%

Cochrane-Amitage trend test: p<0.0001 for both groups.

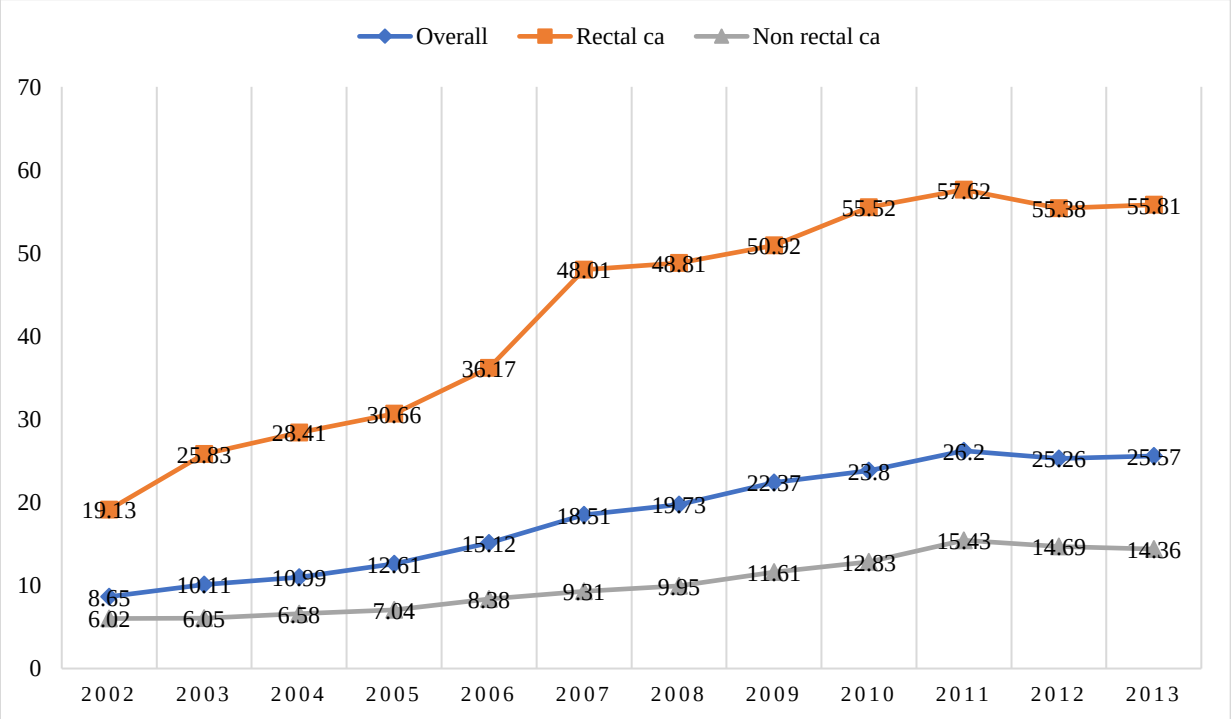


Figure 2. Trend of ileostomies from 2002-2013

3.3 Descriptive aggregate morbidity and mortality

In the overall patient cohort of 25,491 patients, 4,658 (18%) patients had DLIs. The 30-day, 90-day, and 1-year mortality of these patients was 1.2%, 2.2%, and 5.1%, respectively. The 30-day and 90-day mortality associated with ileostomy reversal was 0.6% and 0.9%, respectively.

After index surgery and initial DLI, the rate of reoperation was 5.5%, hospital readmission was 13.4%, major complication was 28.5%, deep organ/space infection requiring percutaneous intervention was 5.2%, acute renal failure requiring hospitalization was 10.4%, development of ventral hernia was 4.0%, diagnosis of bowel obstruction requiring hospitalization was 10.6%, bleeding requiring transfusion was 17.9%, and diagnosis of enterocutaneous fistula was 2.1% (Figure 3).

A total of 4,041 patients (86.8%) with an initial DLI had their ileostomy reversed. After ileostomy reversal, the rate of major complication was 10.3%, deep organ/space infection was 1.7%, bowel obstruction was 7.0%, diagnosis of ventral hernia was 10.3%, and diagnosis of colitis was 2.7% (Figure 4).

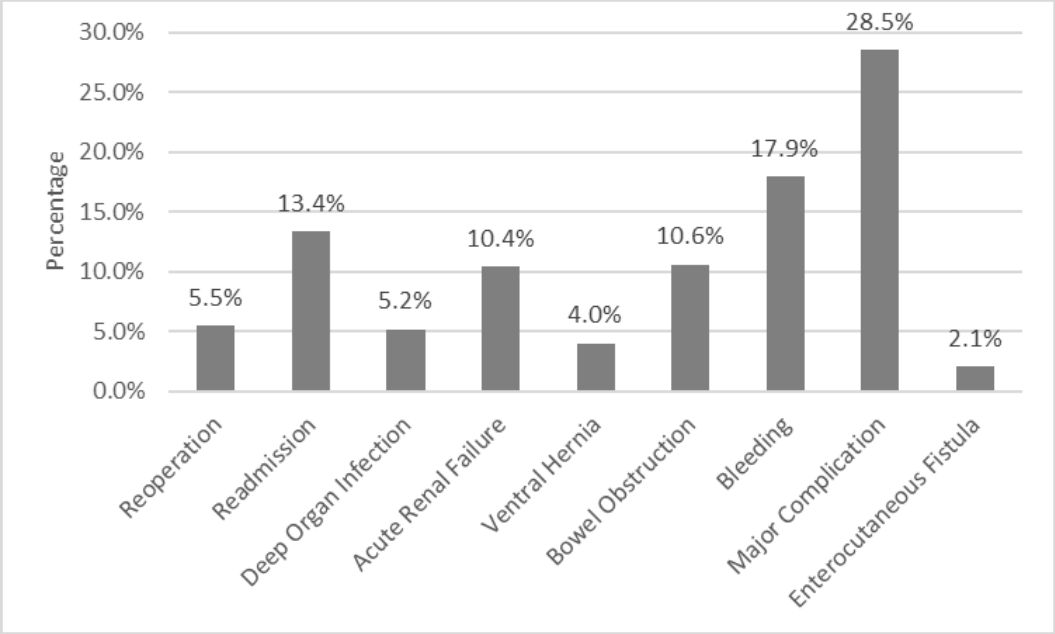


Figure 3. Cumulative morbidity after index surgery

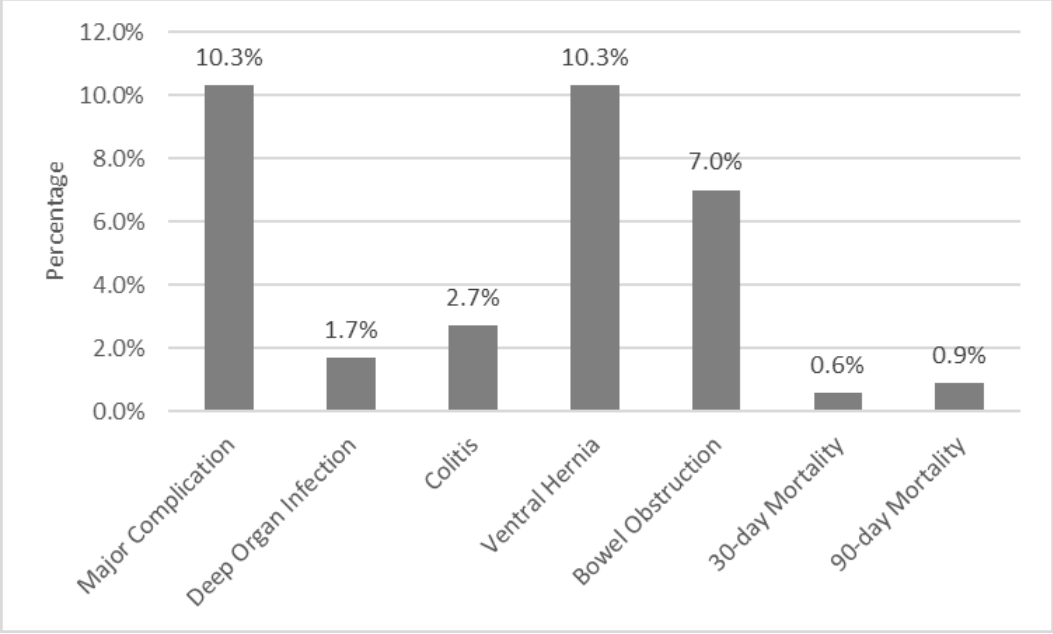


Figure 4. Cumulative morbidity after ileostomy reversal

3.4 Peri-operative outcomes compared to non-ileostomy patients

The perioperative outcomes of interest all occurred within 30-days of index surgery date. The outcomes of interests included hospital length of stay, reoperation, readmission, major complication, bleeding requiring transfusion, deep space infection requiring percutaneous intervention, and 30-day mortality. Multi-variate analysis was performed on the following outcomes: reoperation, major-complication, readmission, deep organ/space infection, and bleeding requiring blood transfusion.

3.4.1 Rectal cancer subgroup

Among patients with rectal cancer, DLI was associated with higher odds of major complication (OR 1.24, 95% CI 1.07-1.42; $p = 0.004$), and hospital readmission (OR 1.57, 95% CI 1.34-1.83; $p < 0.0001$). However, DLI was also associated with lower odds of reoperation (OR 0.53, 95% CI 0.39-0.72; $p < 0.0001$). There was no difference in the rate of deep organ/space infection (OR 0.99, 95% CI 0.73-1.35; $p = 0.96$) or the need for blood transfusions (OR 1.04, 95% CI 0.88-1.23; $p = 0.616$) (Table 6,8-10).

Although an adjusted model could not be investigated for 30-day mortality due to the small number of events, ileostomy was associated with a non-significant reduction in risk of 30-mortality in an unadjusted analysis (1.2% versus 1.8%; OR 0.66, 95% CI 0.43-1.01; $p = 0.05$). Median hospital length of stay was 9 days (IQR 7-13 days) in the ileostomy group and 8 days (IQR 6-10 days) in the non-ileostomy group ($p < 0.001$) (Table 7).

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Table 6. Adjusted and non-adjusted perioperative outcomes in the rectal cancer subgroup

Outcome	No ileostomy n = 3,446	Ileostomy n = 2,700	Unadjusted Odds Ratio (95% CI)	Unadjusted *p* - value	Adjusted Odds Ratio (95% CI)	Adjusted *p*- value
Reoperation	244 (7.1%)	121 (4.5%)	0.62 (0.49-0.77)	<.0001	0.53 (0.39-0.72)	<.0001
Major complication	865 (25.1%)	695 (25.7%)	1.03 (0.92-1.16)	0.568	1.24 (1.07-1.42)	0.004
Readmission	396 (11.6%)	508 (18.9%)	1.78 (1.55-2.05)	<.0001	1.57 (1.34-1.83)	<.0001
Deep space infection	144 (4.2%)	141 (5.2%)	1.26 (1.00-1.60)	0.054	0.99 (0.73-1.35)	0.956
Blood transfusion	573 (16.6%)	395 (14.6%)	0.86 (0.75-0.99)	0.033	1.04 (0.88-1.23)	0.616

Table 7. Overall hospital length of stay in rectal cancer patients

Outcome	Overall		No ileostomy		Ileostomy		*p* - value
	Mean (STD)	Median (IQR)	Mean (STD)	Median (IQR)	Mean (STD)	Median (IQR)	
Post-operative length of stay	10.29 (5.76)	8 (7-12)	9.77 (5.69)	8 (7-11)	10.96 (5.80)	9 (7-13)	<.001
Total bed days within 30 days	11.32 (6.45)	9 (7-13)	10.72 (6.45)	8 (7-12)	12.08 (6.38)	10 (8-15)	<.001
Total bed days within 1 year	19.2 (19.3)	14 (8-22)	16.3 (19.9)	9 (7-17)	22.9 (18.0)	18 (13-26)	<.001

STD = Standard deviation, IQR = Interquartile ratio.

Table 8. Covariates adjusted for perioperative outcomes reoperation and major complication in rectal cancer patients

Covariate	Reoperation		Major Complication	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Ileostomy*	0.53 (0.39-0.72)	<.0001	1.24 (1.07-1.42)	0.004
Age (per 10-year increase)	0.97 (0.88-1.06)	0.495	1.47 (1.38-1.55)	<.0001
Sex (male vs female)	1.97 (1.55-2.51)	<.0001	1.07 (0.94-1.22)	0.290
RUB (moderate vs low)	1.18 (0.87-1.61)	0.289	1.25 (1.07-1.47)	0.005
RUB (high vs low)	1.03 (0.65-1.62)	0.900	1.30 (1.04-1.63)	0.024
Radio or chemotherapy*	1.09 (0.83-1.44)	0.522	0.93 (0.80-1.09)	0.363
ASA (0-2 vs 3-4)	1.06 (0.84-1.35)	0.633	1.62 (1.41-1.86)	<.0001
Teaching institution*	1.10 (0.85-1.41)	0.466	0.98 (0.84-1.15)	0.819
High surgeon volume*	0.82 (0.66-1.02)	0.067	0.84 (0.74-0.96)	0.012
Fiscal year (2003 vs 2002)	1.54 (0.78-3.02)	0.213	0.97 (0.72-1.31)	0.855
Fiscal year (2004 vs 2002)	0.96 (0.48-1.90)	0.898	0.86 (0.63-1.18)	0.345
Fiscal year (2005 vs 2002)	1.61 (0.87-3.01)	0.133	0.88 (0.65-1.21)	0.442
Fiscal year (2006 vs 2002)	1.62 (0.85-3.07)	0.145	0.82 (0.59-1.14)	0.238
Fiscal year (2007 vs 2002)	2.16 (1.15-4.06)	0.016	0.70 (0.50-0.99)	0.043
Fiscal year (2008 vs 2002)	2.77 (1.53-5.02)	0.001	0.82 (0.60-1.11)	0.201
Fiscal year (2009 vs 2002)	1.49 (0.78-2.83)	0.227	0.66 (0.47-0.92)	0.014
Fiscal year (2010 vs 2002)	1.72 (0.91-3.26)	0.098	0.66 (0.47-0.92)	0.014
Fiscal year (2011 vs 2002)	1.94 (1.02-3.68)	0.042	0.71 (0.52-0.98)	0.034
Fiscal year (2012 vs 2002)	1.40 (0.72-2.70)	0.320	0.62 (0.45-0.86)	0.004
Fiscal year (2013 vs 2002)	1.92 (1.05-3.50)	0.033	0.81 (0.60-1.10)	0.173

*Yes vs no; OR = Odds ratio, CI = Confidence interval.

Table 9. Covariates adjusted for perioperative outcomes readmission and deep organ infection in rectal cancer patients

Covariate	Readmission		Deep Organ Infection	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Ileostomy*	1.57 (1.34-1.83)	<.0001	0.99 (0.73-1.35)	0.956
Age (per 10-year increase)	0.98 (0.92-1.05)	0.554	0.95 (0.86-1.05)	0.275
Sex (male vs female)	1.01 (0.88-1.16)	0.912	1.47 (1.12-1.93)	0.006
RUB (moderate vs low)	1.37 (1.13-1.67)	0.002	0.95 (0.66-1.37)	0.799
RUB (high vs low)	1.47 (1.09-1.98)	0.011	1.22 (0.79-1.86)	0.371
Radio or chemotherapy*	1.29 (1.10-1.51)	0.002	0.95 (0.70-1.28)	0.720
ASA (0-2 vs 3-4)	1.24 (1.05-1.46)	0.010	1.12 (0.86-1.46)	0.415
Teaching institution*	0.97 (0.83-1.14)	0.717	1.39 (1.01-1.92)	0.044
High surgeon volume*	0.98 (0.85-1.14)	0.802	1.09 (0.83-1.44)	0.543
Fiscal year (2003 vs 2002)	0.71 (0.44-1.14)	0.155	3.00 (0.83-10.80)	0.094
Fiscal year (2004 vs 2002)	1.09 (0.72-1.64)	0.680	2.34 (0.60-9.07)	0.219
Fiscal year (2005 vs 2002)	0.86 (0.55-1.34)	0.493	5.53 (1.67-18.29)	0.005
Fiscal year (2006 vs 2002)	1.04 (0.68-1.60)	0.854	7.53 (2.3-24.68)	0.001
Fiscal year (2007 vs 2002)	1.06 (0.68-1.66)	0.798	5.63 (1.65-19.14)	0.006
Fiscal year (2008 vs 2002)	0.90 (0.60-1.36)	0.626	7.21 (2.18-23.84)	0.001
Fiscal year (2009 vs 2002)	0.88 (0.58-1.34)	0.545	6.34 (1.91-21.04)	0.003
Fiscal year (2010 vs 2002)	0.99 (0.65-1.49)	0.949	4.54 (1.32-15.62)	0.017
Fiscal year (2011 vs 2002)	1.14 (0.76-1.71)	0.522	8.77 (2.62-29.37)	0.000
Fiscal year (2012 vs 2002)	1.11 (0.74-1.67)	0.622	8.75 (2.67-28.62)	0.000
Fiscal year (2013 vs 2002)	1.08 (0.70-1.65)	0.733	8.87 (2.70-29.19)	0.000

*Yes vs no; OR = Odds ratio, CI = Confidence interval.

Table 10. Covariates adjusted for perioperative outcome blood transfusion in rectal cancer patients

Covariate	Blood Transfusion	
	OR (95% CI)	*p*-value
Ileostomy*	1.04 (0.88-1.23)	0.616
Age (per 10-year increase)	1.44 (1.34-1.53)	<.0001
Sex (male vs female)	0.77 (0.67-0.89)	0.001
RUB (moderate vs low)	1.19 (0.99-1.43)	0.072
RUB (high vs low)	1.11 (0.85-1.45)	0.432
Radio or chemotherapy*	0.97 (0.80-1.17)	0.746
ASA (0-2 vs 3-4)	1.75 (1.49-2.07)	<.0001
Teaching institution*	1.06 (0.87-1.28)	0.577
High surgeon volume*	0.86 (0.73-1.01)	0.066
Fiscal year (2003 vs 2002)	0.99 (0.72-1.36)	0.939
Fiscal year (2004 vs 2002)	0.80 (0.55-1.17)	0.250
Fiscal year (2005 vs 2002)	0.85 (0.60-1.23)	0.390
Fiscal year (2006 vs 2002)	0.86 (0.59-1.24)	0.419
Fiscal year (2007 vs 2002)	0.79 (0.53-1.17)	0.233
Fiscal year (2008 vs 2002)	0.79 (0.56-1.13)	0.201
Fiscal year (2009 vs 2002)	0.65 (0.45-0.94)	0.023
Fiscal year (2010 vs 2002)	0.61 (0.42-0.89)	0.010
Fiscal year (2011 vs 2002)	0.58 (0.39-0.84)	0.004
Fiscal year (2012 vs 2002)	0.44 (0.30-0.65)	<.0001
Fiscal year (2013 vs 2002)	0.63 (0.44-0.91)	0.013

*Yes vs no; OR = Odds ratio, CI = Confidence interval.

3.4.2 Non-rectal cancer subgroup

Among patients without rectal cancer, DLI was associated with higher odds of reoperation (OR 1.49, 95% CI 1.23-1.83; $p < 0.0001$), major complication (OR 1.59, 95% CI 1.44-1.76; $p < 0.0001$), hospital admission (OR 2.38, 95% CI 2.08-2.72; $p < 0.0001$), deep organ/space infection (OR 1.67, 95% CI 1.29-2.17; $p < 0.0001$), and blood transfusion (OR 1.57, 95% CI 1.39-1.76; $p < 0.0001$) (Table 11-14).

Although a smaller percentage of patients in the ileostomy group died within 30-days of surgery, this difference was non-significant in an unadjusted analysis (1.2% versus 1.6%; OR 0.75, 95% CI 0.49-1.16; $p = 0.19$). Median hospital length of stay was eight (IQR 6-10) days for patients in the no ileostomy group and nine (IQR 8-14) days for patients in the ileostomy group ($p < 0.001$) (Table 15).

Table 11. Adjusted and non-adjusted perioperative outcomes in the non-rectal cancer subgroup

Outcome	**No ileostomy**	**Ileostomy**	**Unadjusted**		**Adjusted**	
	n = 17,387	**n = 1,958**	**Odds Ratio (95% CI)**	***p* - value**	**Odds Ratio (95% CI)**	***p*- value**
Reoperation	727 (4.2%)	133 (6.8%)	1.67 (1.38-2.02)	<.0001	1.50 (1.23-1.83)	<.0001
Major complication	3,999 (23.0%)	632 (32.3%)	1.60 (1.44-1.77)	<.0001	1.59 (1.44-1.76)	<.0001
Readmission	1,459 (8.4%)	363 (18.7%)	2.50 (2.20-2.83)	<.0001	2.38 (2.08-2.72)	<.0001
Deep space infection	417 (2.4%)	99 (5.1%)	2.17 (1.73-2.71)	<.0001	1.67 (1.29-2.17)	0.0001
Blood transfusion	2,724 (15.7%)	438 (22.4%)	1.55 (1.38-1.74)	<.0001	1.57 (1.40-1.76)	<.0001

Table 12. Covariates adjusted for perioperative outcomes reoperation and major complication in non-rectal cancer patients

Covariate	Reoperation		Major Complication	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Ileostomy*	1.50 (1.23-1.83)	<.0001	1.59 (1.44-1.76)	<.0001
Age (per 10-year increase)	1.04 (0.98-1.09)	0.229	1.33 (1.28-1.37)	<.0001
Sex (male vs female)	1.61 (1.40-1.86)	<.0001	0.77 (0.72-0.83)	<.0001
RUB (moderate vs low)	1.01 (0.84-1.21)	0.959	1.15 (1.05-1.26)	0.002
RUB (high vs low)	1.15 (0.92-1.44)	0.222	1.44 (1.29-1.60)	<.0001
Colon/rectosigmoid cancer*	0.83 (0.71-0.96)	0.016	0.93 (0.86-1.00)	0.050
ASA (0-2 vs 3-4)	1.35 (1.16-1.58)	<.0001	1.99 (1.83-2.16)	<.0001
Teaching institution*	1.27 (1.05-1.54)	0.015	1.45 (1.25-1.68)	<.0001
High surgeon volume*	0.73 (0.63-0.84)	<.0001	0.84 (0.77-0.91)	<.0001
Fiscal year (2003 vs 2002)	0.84 (0.6-1.18)	0.315	0.91 (0.78-1.06)	0.233
Fiscal year (2004 vs 2002)	1.00 (0.71-1.41)	0.992	0.85 (0.72-1.00)	0.057
Fiscal year (2005 vs 2002)	0.88 (0.62-1.25)	0.484	0.87 (0.75-1.01)	0.061
Fiscal year (2006 vs 2002)	1.09 (0.78-1.54)	0.612	0.81 (0.68-0.95)	0.010
Fiscal year (2007 vs 2002)	1.27 (0.93-1.73)	0.139	0.78 (0.64-0.93)	0.007
Fiscal year (2008 vs 2002)	1.30 (0.92-1.84)	0.136	0.78 (0.66-0.92)	0.003
Fiscal year (2009 vs 2002)	1.21 (0.87-1.7)	0.265	0.67 (0.57-0.80)	<.0001
Fiscal year (2010 vs 2002)	1.19 (0.85-1.66)	0.304	0.71 (0.60-0.84)	<.0001
Fiscal year (2011 vs 2002)	1.03 (0.73-1.46)	0.848	0.74 (0.63-0.88)	0.001
Fiscal year (2012 vs 2002)	1.19 (0.84-1.67)	0.337	0.74 (0.62-0.87)	0.001
Fiscal year (2013 vs 2002)	0.98 (0.70-1.39)	0.918	0.79 (0.66-0.94)	0.008

*Yes vs no; OR = Odds ratio, CI = Confidence interval.

Table 13. Covariates adjusted for perioperative outcomes readmission and blood transfusion in non-rectal cancer patients

Covariate	Readmission		Blood Transfusion	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Ileostomy*	2.38 (2.08-2.72)	<.0001	1.57 (1.4-1.76)	<.0001
Age (per 10-year increase)	1.03 (0.99-1.07)	0.142	1.29 (1.24-1.34)	<.0001
Sex (male vs female)	0.94 (0.85-1.04)	0.194	0.62 (0.57-0.67)	<.0001
RUB (moderate vs low)	1.22 (1.08-1.39)	0.002	1.10 (0.99-1.21)	0.074
RUB (high vs low)	1.45 (1.24-1.69)	<.0001	1.36 (1.20-1.54)	<.0001
Colon/rectosigmoid cancer*	0.93 (0.84-1.03)	0.136	0.97 (0.89-1.05)	0.437
ASA (0-2 vs 3-4)	1.21 (1.09-1.35)	0.00	1.99 (1.81-2.19)	<.0001
Teaching institution*	1.26 (1.11-1.43)	0.00	1.52 (1.28-1.80)	<.0001
High surgeon volume*	0.92 (0.83-1.03)	0.14	0.80 (0.72-0.87)	<.0001
Fiscal year (2003 vs 2002)	1.19 (0.93-1.52)	0.164	0.88 (0.74-1.04)	0.141
Fiscal year (2004 vs 2002)	1.17 (0.92-1.49)	0.19	0.86 (0.72-1.03)	0.101
Fiscal year (2005 vs 2002)	1.09 (0.84-1.41)	0.514	0.83 (0.70-0.98)	0.026
Fiscal year (2006 vs 2002)	0.86 (0.65-1.13)	0.271	0.77 (0.63-0.94)	0.008
Fiscal year (2007 vs 2002)	1.21 (0.93-1.56)	0.155	0.68 (0.54-0.84)	0.000
Fiscal year (2008 vs 2002)	1.41 (1.09-1.82)	0.008	0.71 (0.58-0.86)	0.001
Fiscal year (2009 vs 2002)	1.03 (0.79-1.34)	0.855	0.65 (0.54-0.79)	<.0001
Fiscal year (2010 vs 2002)	1.23 (0.94-1.60)	0.128	0.63 (0.52-0.77)	<.0001
Fiscal year (2011 vs 2002)	1.04 (0.8-1.34)	0.768	0.68 (0.56-0.83)	0.000
Fiscal year (2012 vs 2002)	1.05 (0.81-1.36)	0.711	0.58 (0.47-0.70)	<.0001
Fiscal year (2013 vs 2002)	1.15 (0.89-1.49)	0.300	0.62 (0.50-0.76)	<.0001

*Yes vs no; OR = Odds ratio, CI = Confidence interval.

Table 14. Covariates adjusted for perioperative outcome deep organ infection in non-rectal cancer patients

Covariate	Deep Organ Infection	
	OR (95% CI)	*p*-value
Ileostomy*	1.67 (1.29-2.17)	0.000
Age (per 10-year increase)	0.93 (0.86-0.99)	0.031
Sex (male vs female)	1.47 (1.21-1.77)	<.0001
RUB (moderate vs low)	1.18 (0.92-1.51)	0.190
RUB (high vs low)	1.41 (1.06-1.88)	0.019
Colon/rectosigmoid cancer*	0.86 (0.72-1.04)	0.116
ASA (0-2 vs 3-4)	1.31 (1.08-1.60)	0.007
Teaching institution*	1.80 (1.42-2.29)	<.0001
High surgeon volume*	0.86 (0.70-1.05)	0.126
Fiscal year (2003 vs 2002)	0.88 (0.46-1.68)	0.694
Fiscal year (2004 vs 2002)	1.06 (0.62-1.80)	0.834
Fiscal year (2005 vs 2002)	1.38 (0.79-2.42)	0.256
Fiscal year (2006 vs 2002)	1.60 (0.93-2.75)	0.093
Fiscal year (2007 vs 2002)	2.20 (1.29-3.77)	0.004
Fiscal year (2008 vs 2002)	2.34 (1.38-3.97)	0.002
Fiscal year (2009 vs 2002)	2.11 (1.27-3.50)	0.004
Fiscal year (2010 vs 2002)	1.76 (0.99-3.11)	0.054
Fiscal year (2011 vs 2002)	2.37 (1.43-3.91)	0.001
Fiscal year (2012 vs 2002)	2.32 (1.39-3.87)	0.001
Fiscal year (2013 vs 2002)	2.24 (1.32-3.77)	0.003

*Yes vs no; OR = Odds ratio, CI = Confidence interval.

Table 15. Overall hospital length of stay in non-rectal cancer patients

Outcome	Overall		No ileostomy		Ileostomy		*p* - value
	Mean (STD)	Median (IQR)	Mean (STD)	Median (IQR)	Mean (STD)	Median (IQR)	
Post-operative length of stay	9.17 (5.31)	8 (6-10)	8.89 (5.11)	8 (6-10)	11.63 (6.30)	9 (8-14)	<.001
Total bed days within 30 days	9.82 (5.89)	8 (6-11)	9.48 (5.68)	8 (6-10)	12.80 (6.84)	11 (8-16)	<.001
Total bed days within 1 year	14.4 (16.9)	9 (7-15)	13.2 (15.8)	8 (6-14)	25.1 (21.4)	19 (14-29)	<.001

STD = Standard deviation, IQR = Interquartile ratio.

3.5 Long-term outcomes compared to non-ileostomy patients

Long-term outcomes were captured within 180 days of the index surgery and included acute renal failure requiring hospitalization, bowel obstruction requiring hospital admission, abdominal hernia, enterocutaneous fistula, and 90-day and 1-year mortality.

3.5.1 Rectal cancer subgroup

DLIs were associated with significantly higher rates of acute renal failure requiring hospitalization (OR 4.15, 95% CI 3.14-5.47; $p < 0.0001$). One-year mortality was lower in rectal cancer patients with DLIs, although the difference was not statistically significant (OR 0.77, 95% CI 0.56-1.00; $p = 0.05$) (Table 16, 18).

For unadjusted outcomes of rectal cancer patients, 90-day mortality was significantly lower in the ileostomy group (OR 0.66, 95% CI 0.47-0.92; $p = 0.01$). However, ileostomy patients did have much higher odds of ventral hernia (OR 2.4, 95% CI 1.66-3.46; $p < 0.0001$) and bowel

obstruction (OR 14.5, 95% CI 9.72-21.57; $p < 0.0001$). There was no between group difference in the number of enterocutaneous fistulas (OR 0.64, 95% CI 0.34-1.19; $p = 0.15$) (Table 17).

Table 16. Unadjusted and adjusted long-term outcomes in rectal cancer patients

Outcome	No ileostomy n = 3,446	Ileostomy n = 2,700	Unadjusted Odds Ratio (95% CI)	*p* - value	Adjusted Odds Ratio (95% CI)	*p*-value
Renal failure	90 (2.6%)	272 (10.1%)	4.18 (3.27-5.33)	<.0001	4.15 (3.14-5.47)	<.0001
Mortality (1 year)	233 (6.8%)	121 (4.5%)	0.64 (0.52-0.81)	0.000	0.77 (0.59-1.00)	0.004

Table 17. Unadjusted long-term outcomes for rectal cancer patients; after ileostomy reversal

Outcome	Overall n=6,146	No Ileostomy n=3,446	Ileostomy n=2,700	OR (95% CI)	*p*-value
Mortality (90-day)	155 (2.5%)	102 (3.0%)	53 (2.0%)	0.66 (0.47-0.92)	0.014
Ostomy-related complication	454 (7.4%)	96 (2.8%)	358 (13.3%)	5.33 (4.23-6.72)	<.0001
Ventral hernia	128 (2.1%)	45 (1.3%)	83 (3.1%)	2.4 (1.66-3.46)	<.0001
Bowel obstruction or ileus	304 (4.9%)	27 (0.8%)	277 (10.3%)	14.48 (9.72-21.57)	<.0001
Enterocutaneous fistula	45 (0.7%)	30 (0.9%)	15 (0.6%)	0.64 (0.34-1.19)	0.154

OR = Odds ratio, CI = Confidence interval.

Table 18. Co-variates adjusted for long-term outcomes in rectal cancer patients

Covariate	Mortality (1-year)		Renal Failure	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Ileostomy*	0.77 (0.59-1.00)	0.053	4.15 (3.14-5.47)	<.0001
Age (per 10-year increase)	1.63 (1.45-1.84)	<.0001	1.49 (1.35-1.65)	<.0001
Sex (male vs female)	1.64 (1.28-2.10)	0.000	1.32 (1.03-1.69)	0.03
RUB (moderate vs low)	1.16 (0.89-1.51)	0.287	1.18 (0.87-1.60)	0.283
RUB (high vs low)	1.27 (0.87-1.85)	0.212	1.06 (0.68-1.65)	0.798
Radio or chemotherapy*	0.99 (0.75-1.30)	0.933	1.14 (0.91-1.43)	0.272
ASA (0-2 vs 3-4)	1.89 (1.42-2.51)	<.0001	1.65 (1.27-2.13)	0.000
Teaching institution*	0.75 (0.56-1.00)	0.047	0.83 (0.63-1.08)	0.168
High surgeon volume*	0.91 (0.70-1.16)	0.436	1.04 (0.83-1.29)	0.759
Fiscal year (2003 vs 2002)	0.74 (0.41-1.33)	0.313	0.72 (0.30-1.78)	0.481
Fiscal year (2004 vs 2002)	0.90 (0.55-1.50)	0.694	1.53 (0.74-3.15)	0.254
Fiscal year (2005 vs 2002)	0.76 (0.45-1.28)	0.307	1.18 (0.54-2.54)	0.683
Fiscal year (2006 vs 2002)	0.64 (0.36-1.12)	0.116	1.37 (0.67-2.83)	0.388
Fiscal year (2007 vs 2002)	0.89 (0.51-1.54)	0.676	1.21 (0.56-2.59)	0.626
Fiscal year (2008 vs 2002)	0.79 (0.44-1.39)	0.407	1.52 (0.72-3.21)	0.269
Fiscal year (2009 vs 2002)	0.57 (0.32-1.02)	0.059	1.37 (0.68-2.76)	0.373
Fiscal year (2010 vs 2002)	0.61 (0.34-1.09)	0.093	1.30 (0.63-2.65)	0.479
Fiscal year (2011 vs 2002)	0.66 (0.38-1.14)	0.135	1.36 (0.67-2.77)	0.401
Fiscal year (2012 vs 2002)	0.65 (0.39-1.09)	0.102	2.09 (1.05-4.16)	0.037
Fiscal year (2013 vs 2002)	0.56 (0.31-1.00)	0.050	2.05 (1.05-4.00)	0.036

*Yes vs no; OR = Odds ratio, CI = Confidence interval.

3.5.2 Non-rectal cancer subgroup

Among patient without rectal cancer, DLIs were also associated with significantly higher odds of acute renal failure (OR 5.76, 95% CI 4.66-7.12; $p < 0.0001$). There was no significant difference in one-year mortality (OR 1.15, 95% CI 0.93-1.41; $p = 0.20$) (Table 19, 20).

In terms of unadjusted outcomes, while 90-day mortality did not differ between the groups (OR 1.00, 95% CI 0.74-1.35; $p = 0.99$), patients with an ileostomy did have significantly higher odds of ventral hernia (OR 2.37, 95% CI 1.90-2.97; $p < 0.0001$), bowel obstruction (OR 44.5, 95% CI 32.46-61.15; $p < 0.0001$, and enterocutaneous fistula (OR 2.53, 95% CI 1.98-3.23; $p < 0.0001$) (Table 21).

Table 19. Unadjusted and adjusted long-term outcomes in non-rectal cancer patients

Outcome	**No ileostomy**	**Ileostomy**	**Unadjusted**		**Adjusted**	
	n = 17,387	**n = 1,958**	**Odds Ratio (95% CI)**	***p* - value**	**Odds Ratio (95% CI)**	***p*-value**
Renal failure	348 (2.0%)	212 (10.8%)	5.95 (4.97-7.10)	<.0001	5.76 (4.66-7.12)	<.0001
Mortality (1 year)	988 (5.7%)	117 (6.0%)	1.60 (1.44-1.77)	0.590	1.15 (0.93-1.42)	<.200

Table 20. Covariates adjusted for long-term outcomes in non-rectal cancer patients

Covariate	Mortality (1-year)		Renal Failure	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Ileostomy*	1.15 (0.93-1.42)	0.200	5.76 (4.66-7.12)	<.0001
Age (per 10-year increase)	1.72 (1.60-1.85)	<.0001	1.53 (1.40-1.66)	<.0001
Sex (male vs female)	1.21 (1.05-1.39)	0.008	1.23 (1.05-1.45)	0.013
RUB (moderate vs low)	0.97 (0.82-1.14)	0.698	1.17 (0.94-1.45)	0.166
RUB (high vs low)	1.24 (1.04-1.49)	0.019	1.58 (1.23-2.04)	0.000
Colon/rectosigmoid*	1.33 (1.14-1.55)	0.000	0.98 (0.82-1.18)	0.818
ASA (0-2 vs 3-4)	2.17 (1.87-2.51)	<.0001	1.93 (1.56-2.38)	<.0001
Teaching institution*	1.07 (0.88-1.30)	0.498	1.08 (0.87-1.35)	0.465
High surgeon volume*	0.85 (0.74-0.97)	0.017	1.13 (0.94-1.36)	0.200
Fiscal year (2003 vs 2002)	0.96 (0.72-1.27)	0.766	0.96 (0.57-1.60)	0.865
Fiscal year (2004 vs 2002)	0.79 (0.60-1.06)	0.112	1.18 (0.70-1.97)	0.541
Fiscal year (2005 vs 2002)	0.88 (0.68-1.14)	0.342	1.01 (0.61-1.66)	0.984
Fiscal year (2006 vs 2002)	0.69 (0.52-0.93)	0.013	1.14 (0.71-1.83)	0.586
Fiscal year (2007 vs 2002)	0.72 (0.54-0.97)	0.028	1.16 (0.72-1.89)	0.542
Fiscal year (2008 vs 2002)	0.54 (0.40-0.75)	0.000	1.33 (0.81-2.18)	0.265
Fiscal year (2009 vs 2002)	0.63 (0.46-0.85)	0.003	1.36 (0.82-2.25)	0.239
Fiscal year (2010 vs 2002)	0.61 (0.45-0.82)	0.001	1.50 (0.95-2.35)	0.080
Fiscal year (2011 vs 2002)	0.70 (0.53-0.93)	0.013	2.01 (1.3-3.11)	0.002
Fiscal year (2012 vs 2002)	0.46 (0.33-0.63)	<.0001	1.65 (1.02-2.65)	0.040
Fiscal year (2013 vs 2002)	0.49 (0.36-0.68)	<.0001	1.88 (1.22-2.90)	0.004

*Yes vs no; OR = Odds ratio, CI = Confidence interval.

Table 21. Unadjusted long-term outcomes for non-rectal cancer patients

Outcome	Overall	No Ileostomy	Ileostomy	OR (95% CI)	p -value
	n = 19, 345	n - 17,387	n = 1958		
Mortality (90-day)	484 (2.5%)	435 (2.5%)	49 (2.5%)	1.00 (0.74-1.35)	0.999
Ventral hernia	491 (2.5%)	390 (2.2%)	101 (5.2%)	2.37 (1.90-2.97)	<.0001
Bowel obstruction	263 (1.4%)	48 (0.3%)	215 (11.0%)	44.55 (32.46-61.15)	<.0001
Ostomy related complications	1082 (5.6%)	714 (4.1%)	368 (18.8%)	5.41 (4.72-6.19)	<.0001
Enterocutaneous fistula	387 (2.0%)	303 (1.7%)	84 (4.3%)	2.53(1.98-3.23)	<.0001

OR = Odds ratio, CI = Confidence interval.

3.6 Timing of ileostomy reversal and permanent ostomies

Out of 4658 patients that had DLIs, 4041 patients had ileostomy reversals, leaving 617 (13.2%) patients with a permanent ileostomy. The mean time to reversal was 231 days (STD 125 days) and the median time to reversal was 214 days (IQR 133-301 days). The majority of patients had their ileostomy reversed between 3 and 12 months (76.9%). Ten percent of patients had their ileostomy reversed very early (before 3 months) and the rest (13.1%) had their reversal between 12-24 months (Table 22).

Table 22. Timing of ileostomy reversals

Time to reversal	n	Number of patients at each interval	Cumulative % of all patients with an ileostomy	Individual % at each interval with a reversal	Cumulative % of patients with a reversal
Within 1 month	16	16	0.34%	0.39%	0.40%
Within 3 months	391	375	8.39%	9.28%	9.68%
Within 6 months	1559	1168	33.47%	28.90%	38.58%
Within 9 months	2706	1147	58.09%	28.38%	66.96%
Within 12 months	3499	793	75.12%	19.62%	86.59%
Within 15 months	3808	309	81.75%	7.65%	94.23%
Within 18 months	3940	132	84.59%	3.27%	97.50%
Within 24 months	4041	101	86.75%	2.50%	100.00%

Chapter IV: Discussion

4.1 Clinical dilemma

Defunctioning loop ileostomies (DLIs) are one of the most common procedures performed by general surgeons and colorectal surgeons, and their utilization is on the rise. According to data from study, there was a 300% increase in the number of DLIs performed in Ontario from 2002 to 2013 (Figure 2). DLIs became popular after a number of randomized controlled trials (RCTs) demonstrated its benefit in decreasing symptomatic anastomotic leaks (AL) after low anterior resection (LAR), and especially as surgeons began to perform lower resections to preserve sphincter function [3,20,51]. However, their use has been extended beyond the indications of those RCTs and some surgeons are forming them whenever they're not confident about the anastomosis. As more DLIs are being used, surgeons are beginning to see more complications associated with these ileostomies, both in clinical practice and in clinical research [9,25,26,29,31,35-37,52].

Although there have been studies analyzing the morbidity associated with DLIs, none of these studies followed the same patients from inception of the ostomy to ileostomy reversal. This is one of the main strengths of the current study. Most studies were also conducted in a retrospective nature; however, the databases utilized for the current study used population-level data [26,31,52]. Another strength of this study is that we used administrative databases that collect all available patient data, making it a real-life representation of the patient cohort in the time period selected. To our knowledge, this is one of the largest patient cohorts to date to investigate outcomes following DLI.

One of the biggest limitations of this retrospective analysis, which is important to address before interpretation of the outcomes, is the heterogeneous nature of the patient cohort. In an effort to produce a powerful study to allow for multivariate analysis, the definition of the patient cohort was set widely. Any patient undergoing LAR was included. The indications for surgery varied, ranging from cancer resections, to diverticular disease, to trauma, to inflammatory bowel disease. To accommodate some of the heterogeneity, two major adjustments were made: first, patients were separated into subgroups of rectal cancer patients versus non-rectal cancer patients and second, multivariate analysis was used to adjust for confounding factors. Overall, these adjustments made the rectal cancer subgroup quite a homogenous cohort of patients. It is possible that rectal cancer patients undergo LAR for other reasons, but, for the vast majority of patients, it can be inferred that these patients underwent surgery for cancer resection. The other subgroup, however, remains heterogeneous and includes colon cancer patients along with patients without cancer. These patients were not excluded from the study because their data still provides valuable information on the frequency of complications associated with DLIs. Nevertheless, results from this subgroup should be interpreted with caution.

4.2 Overall morbidity and mortality

The overall morbidity identified in this study is quite significant and was comparable to outcomes from previous studies, including three other large database cohort studies assessing morbidity and mortality of patients with a LAR and diverting ostomy [26,31,52,53] (Table 23). The overall morbidity observed in the current study was 28.5%. In Nurkin et al.'s retrospective cohort study, patients that underwent low pelvic anastomosis had an overall morbidity of 15.8%, and patients that underwent coloanal anastomosis had an overall morbidity of 11.4% [26] (Table

23). A substantial proportion of patients also experience major complications after ileostomy reversal, including10.3% in this study and 9.3% as reported by Sharma et al. [53] (Table 23). Rates of reoperation, deep space infection, and 30-day mortality were similar in the current study (Table 23). The rate of acute kidney injury (AKI) observed in this study is much higher than the rate reported in previous studies, although Jafari et al. and Nurkin et al. both reported that DLI was associated with increased risk of AKI (OR 2.37, 95% CI 1.22-4.58; $p = 0.011$; OR 3.67) [26,31]. A number of smaller retrospective studies reported similar or higher rates of AKI: 14.5% by Åkesson et al., 18% by Gessler et al., 20.1% by Hayden et al., and 17% Paquette et al. [29,30,36,54].

Table 23. Large population retrospective cohort studies and cumulative morbidity

Author (year)	N	Major complication	Re-operation	AKI	Deep space infection	30-day mortality
Yang (current)	4,658	28.5%	5.5%	10.4%	5.2%	1.2%
Jafari (2013)	991	-	4.5%	1.3%	7.5%	1.3%
Nurkin (2013a)	606	15.8%	5.1%	2.3%	5.6%	1.0%
Nurkin (2013b)	352	11.4%	1.7%	2.3%	5.1%	0%
Chow (2009)	6107	17.3%	-	-	5.0%	0.4%
After ileostomy reversal						
Yang (current)	4,041	10.3%	-	-	1.7%	0.6%
Sharma (2013	5,401	9.3%	4.0%	-	-	0.6%

Note: Nurkin 2013a included low pelvic anastomosis, Nurkin 2013b included coloanal anastomosis

4.3 Rectal cancer patients

In the current study, rectal cancer patients who underwent a LAR with DLI demonstrated significantly lower rates of reoperation (OR 0.53, 95% CI 0.39-0.72; $p < 0.0001$) and 90-day mortality (OR 0.66, 95% CI 0.47-0.92; $p = 0.01$). Although reoperation may be required for

several reasons, AL is one of the main indications for a reoperation within 30 days of DLI. Most other immediate post-operative complications do not require an operation. For example, wound infections and abscesses can be treated with antibiotics and percutaneous drains. If the rate of reoperation is interpreted as a surrogate indicator for significant AL requiring operative intervention, then our results suggest that DLIs are protective against ALs. This finding is consistent with a number of previous studies. Mattheson et al. conducted one of the first RCTs comparing the rate of symptomatic AL in patients undergoing LAR with or without a defunctioning ostomy [20]. In this study, defunctioning stomas included both ileostomies and colostomies. The defunctioned group had a significantly lower rate of symptomatic anastomotic leakage as compared to the non-defunctioned group (10.3% vs 28.0%, OR 3.4, 95% CI 1.6-6.9, $p < 0.001$) [20]. Pisarska et al. conducted a recent systematic review and meta-analysis analyzing the role of DLI in rectal cancer surgery [55]. This study included a total of 2,366 patients from 13 studies, 4 of which were RCTs while 9 were comparative studies. The meta-analysis of RCTs demonstrated a relative risk (RR) reduction of 0.43 in the DLI group (95% CI 0.28-0.67, I2 =35%) [55]. Meta-analysis of the comparative studies also showed a RR reduction of 0.49 (95% CI 0.27-0.87, I2 = 42%) [55]. In 2013, Jafari et al. conducted a similar large population retrospective cohort study that included 6,337 patients from the National Surgery Quality Improvement Project (NSQIP) database [31]. The authors reported that the 991 (16%) patients who received a DLI were significantly less likely to require reoperation than those without an ileostomy (4.5% vs 6.9%, $p < 0.05$) [31].

The decrease in 90-day mortality identified in this study may be attributed to its protective effect against AL. Matthiessen et al. conducted a retrospective cohort study assessing mortality after

elective anterior resection [56]. Out of 6,833 patients, 140 died within 30 days of their initial hospital stay [56]. These 140 patients were analyzed and compared against a randomly chosen control group selected from the remaining 6,693 patients. Within that cohort, 59 patients had documented AL and the leak was considered to be the cause of death or an indirect contributor to the patient's demise [56]. Multivariate analysis in this study demonstrated that male sex, age, Dukes' stage D, intraoperative adverse events, and anastomotic leak were all independent risk factors for post-operative death [56]. Therefore, Matthiessen et al. concluded that AL is highly associated with mortality [56].

The 90-day mortality benefit has not been widely reported in previous studies. The only study that has demonstrated a mortality benefit from a protective ostomy was by Gastinger et al. [2]. They analyzed the data from a prospective multicenter study conducted between January 2000 and December 2001. This study included 2,729 patients and 881 of them underwent a protective stoma after LAR. The protective stoma included both colostomies and ileostomies. In this study, the group with a protective ostomy had a significantly lower in-hospital mortality rate (0.9% vs 2.0%, $p = 0.037$) [2]. Most other studies have not demonstrated a significant difference in risk of mortality [25,31,55,57]. The most recent systematic review and meta-analysis was done by Pisarska et al. [55]. The meta-analysis of both RCTs and comparative non-randomized studies did not demonstrate a significant benefit in terms of mortality (OR 1.12, 95% CI 0.71, 1.77, $p = 0.39$ for RCTs and OR 1.16, 95% CI 0.70, 1.94; $p = 0.56$ for comparative studies) [55]. Even a larger systematic review on diverting ostomies that included both colostomies and ileostomies by Montedori et al. did not demonstrate a mortality benefit [15]. Only RCTs were included in this systematic review and only three studies reported on mortality. Meta-analysis demonstrated an

odds ratio of 0.58 with a 95% CI 0.14, 2.33, $p = 0.44$ for mortality [15]. Therefore, the majority of evidence in the literature suggests that defunctioning ostomies do not provide a mortality benefit; however, the number of studies reporting mortality was limited and none of them analyzed mortality beyond 30 days. The current study followed patients for up to two years after the index surgery and captured mortality for up to one-year after surgery. The rate of reoperation was lower in the DLI group. Anecdotally, patients rarely die within 30-days of their index surgery, especially if they are taken back to the operating room and have a prolonged hospital stay. It is feasible that the mortality benefit of defunctioning ostomies was not identified in previous studies due to the short follow up intervals.

The protective effects of DLIs is contrasted with high rates of morbidity, as we found that DLIs were significantly associated with increased risk of major complication, hospital readmission, longer hospital length of stay, hospital admission for AKI, ventral hernia, and bowel obstruction. Similar complications have been noted in previous studies [2,7,9,25,29,36,37,54,58-59]. This prompts the debate about whether the benefits of DLI out-weighs the morbidity. For cancer patients, AL not only worsens post-operative outcome, morbidity, and mortality, it also worsens oncologic prognosis [16-18]. Therefore, ALs should be minimized as much as possible. The absolute risk of AL for the average rectal cancer patients has been revisited many times throughout the years and the risk is not as high as previously thought. Currently, an anastomotic leak rate of < 8% is considered acceptable [10]. Chun et al. conducted a retrospective cohort study looking at patient characteristics associated with higher risk for AL and concluded that risk factors include male sex (OR 8.56), obesity with BMI > 30 (OR 8.56), age > 65 years (OR 53.34), and hypertension (OR 8.36) [58].

In Nurkin et al.'s large population retrospective cohort analysis, they analyzed patients with low pelvic anastomosis and coloanal anastomoses separately [26]. Patients with a low pelvic anastomosis with or without a DLI did not have significantly different rates of morbidity (pneumonia, unplanned intubation, pulmonary embolus, myocardial infarction, bleeding, deep vein thrombosis, sepsis, septic shock, reoperation, or wound complications) or mortality [26]. The DLI group did, however, have a higher rate of AKI (OR 3.67) [26]. The coloanal group had more complications in patients without a diverting ostomy, including higher rates of unplanned intubation (OR 8.48), ventilation > 48 h (OR 3.67), bleeding (OR 8.31), septic shock (OR 2.48), reoperation (OR 7.11), and serious morbidity (OR 2.35) [26]. This suggests that patients with coloanal anastomosis may benefit from a DLI, whereas this may not be true for patients with a low pelvic anastomosis [26].

One of the most notable complications seen with DLIs is acute kidney injury (AKI). To our knowledge, every study that has analyzed complications related to ostomies has demonstrated significantly higher risk of AKI [25,26,31,33,34,36,51,53,58,60]. The rate of AKI after ileostomy ranges from 11% - 43%, with the current study reporting a rate of 10.4%. AKI is common with an ileostomy because of high ostomy output. The ostomy bypasses the water-absorbing functionality of the colon, thus leading to high volume loss. Often, patients have a difficult time keeping up with the necessary fluid intake, resulting in dehydration and pre-renal AKI. The clinical significance of an AKI is quite significant. Not only does it contribute to increased health-care utilization and cost, it also puts these patients at risk for chronic kidney injury [61-62]. Although no study has followed patients long enough to assess for long-term sequelae of AKI secondary to high ileostomy output, O'Connor et al. conducted a systematic

review looking at long-term outcomes in patients who developed AKI after abdominal surgery. Specifically, they identified a 12.6 relative risk of death in patients who developed AKI [61]. Paquette et al. assessed the impact of readmission due to dehydration after DLI [33]. For patients admitted for dehydration, they stayed a median of 1 day with a range of 1-3 days. For patients admitted for renal failure, patients stayed a median of 4 days with a range of 3-7 days [33]. The cost on the healthcare system per patient was $2,750 USD for dehydration and $9,107 USD for renal failure [33].

4.4 Non-rectal cancer patients

In the current study, the subgroup of patients without rectal cancer was a heterogeneous group of patients. Their specific indications for index surgery could have been discordant, including cancer resection, diverticular disease, resection for inflammatory bowel disease, volvulus, or trauma. Conclusions made with respect to this subgroup may be biased due to confounding factors; however, it was still interesting to analyze the results. From this patient cohort, no associated benefit was seen in the ileostomy group and the ileostomy cohort had significantly more complications including higher risk of major complication, reoperation, readmissions, blood transfusion, deep space infection requiring percutaneous intervention, acute renal failure requiring hospitalization, bowel obstruction, and ventral hernia (Table 6). There is very limited utilization for DLIs other than for cancer resections. The only consideration existing in current literature for performing a LAR with primary anastomosis and DLI is for complicated diverticulitis [63-67]. For complicated diverticulitis, the historic gold standard procedure is a Hartmann's procedure, which is a LAR and end colostomy, leaving a rectal stump [63-67]. An end colostomy can be difficult to reverse and requires a second laparotomy, whereas a DLI is an

easier reversal surgery that can be done locally at the site of the ostomy. Constantinides et al. showed 27% of patients with a Hartmann's end colostomy never got reversed as opposed to 8% of patients with a DLI [65]. Therefore, in current practice, the preferred procedure for diverticulitis is often a LAR with primary anastomosis with or without a defunctioning loop ileostomy. Gawlick & Nirula used the NSQIP database and conducted a retrospective cohort analysis on patients who underwent Hartmann's procedure versus primary anastomosis and DLI [63]. In this study, primary anastomosis with diverting ileostomy was associated with significantly higher mortality in patients with dirty/infected wounds (OR 2.02, 95% CI 1.06-3.85) [63]. There was no significant difference in wound infection, wound dehiscence, or post-operative sepsis. When looking solely at septic patients without dirty/feculent wounds, there was no difference in mortality between the groups [63]. Therefore, this study recommended safe utilization of primary anastomosis with diverting ileostomy for complicated diverticulitis without feculent contamination [63]. To our knowledge, no studies have been conducted investigating the morbidity associated with DLIs in diverticulitis patients.

4.5 Permanent ostomies

In this patient cohort, 13.2% patients were left with a permanent ostomy, which was defined as no evidence of ileostomy reversal at two-years after index surgery. This is comparable to other studies in the literature where the estimated rate of permanent ileostomies ranges from 11-25% [36,40,43,59,68-69]. This is quite significant: more than 1 out of 10 patients who planned to have a temporary ostomy never have it reversed. This has a significant impact on overall patient quality of life (QoL) [41,43-44]. Survey studies have shown that ostomies are associated with decreased physical function and role function, significant concern regarding the ostomy,

significantly decreased confidence in body image, and issues with discomfort, feeling unattractive and decreased sexual activity [41,43-44]. These studies also demonstrate a persistent decrease in QoL even after ileostomy reversal, often associated with changes in bowel function and diminished body image [41,43-45].

There are complications that can occur with a defunctioned colon, such as diversion colitis. The term diversion colitis was coined in 1981 in Glotzer et al.'s case series of ten patients with inflammation of a de-functioned segment of bowel [70]. The specific pathophysiology is unknown but there are two theories. The main theory is that the lack of short-chain fatty acids (SCFA) in the diverted colon causes the inflammation [71-75]. Colonocytes rely on SCFAs as the main source of nutrient [71-75]. Symptoms can include watery diarrhea, lower abdominal discomfort/pain, pelvic pain, anorectal pain, rectal bleeding, tenesmus, mucous discharge, and low-grade fever [71-73]. The majority of patients experience mild to moderate symptoms but 4% will present with severe symptoms [71,73]. The only definitive treatment is re-establishing continuity [71-72].

In the current study, the majority of reversals occurred between 3-12 months after index surgery (76.9%). Thirteen percent had their ileostomy reversed between 1-2 years after surgery and 9.6% got an early ileostomy reversal before 3 months (Table 9). Timing of ileostomy reversal is an important consideration in the operative planning process. An ileostomy that has been there for longer is harder and takes longer to reverse [76]. Furthermore, it has been shown that a colon that has been defunctioned for a longer period of time will take longer to regain function, leading to slower recovery from ileostomy reversal and longer hospital length of stay [76].

4.6 Timing of ileostomy reversal

Timing of ileostomy reversal often depends on whether patients will be undergoing post-operative chemotherapy. Chemotherapy usually lasts between 3 to 6 months and, anecdotally, surgeons wait 4-6 weeks after chemotherapy to let patients recover before reversing the ileostomy. Because of the issues associated with late reversal, it has been proposed that an ultra-early closure be done close to index surgery (within 14 days after index surgery) [77-78]. Two recent systematic reviews and meta-analyses have investigated this specific question. Farag et al. performed a systematic review and meta-analysis of four randomized controlled trials with a total of 446 patients (176 in the early closure group and 270 in delayed closure group) [77]. They identified similar risk of anastomotic leak (RR 0.37, 95% CI 0.10-1.42, $p = 0.15$), anastomotic stenosis (RR 4.79, 95% CI 0.23-09.47, $p = 0.31$), and post-operative complications (RR 0.75, 95% CI 0.48-1.16, $p = 0.19$) between patients with early reversal and late reversal [77]. There was also no significant difference in the duration of operation (mean difference 0.49, 95% CI -1.09-0.12, $p = 0.12$) or hospital length of stay (mean difference -0.44, 95% CI -0.25-0.18, $p = 0.75$) [80]. They concluded that early ileostomy reversal within 14 days was not associated with higher risk than delayed reversal; however, they also did not demonstrate any significant benefit associated with early reversal [77]. Menahem et al. also conducted a systematic review that included comparative studies assessing early closure (≤ 14 days) versus late closure (>8 weeks) [78]. The meta-analysis included six studies, including two retrospective case series, one prospective case series, and three RCTs [78]. In the analysis, there was no significant difference in overall morbidity (OR 0.98, 95% CI 0.63-1.53; $p = 0.95$), anastomotic leak (OR 0.63, 95% CI 0.22-1.78; $p = 0.38$), or reoperation (OR 1.06, 95% CI 0.50-2.26; $p = 0.88$) [78]. There was significantly less small bowel obstruction (OR 0.46, 95% CI 0.24-0.86; $p = 0.02$) and stoma-

related complications (OR 0.11, 95% CI 0.06-0.20; $p < 0.00001$) in the early closure group [78]. Patients in the early closure group did have a significantly higher overall wound infection rate (OR 3.83, 95% CI 2.14-6.86; $p < 0.00001$). The level of evidence in Menahem's meta-analysis was arguably lower than Farag et al. due to higher heterogeneity; however, neither study demonstrated worse outcomes in terms of anastomotic leak or post-operative complications. In fact, Menahem et al. demonstrated benefit with less bowel obstruction and stoma-related complications [78]. This is an avenue that should be explored further in clinical practice.

4.7 Highly selective utilization of defunctioning ileostomies

There is no question that there is benefit with the DLI as demonstrated by this study and a number of studies in the past [3,15,20,22,26,]. However, the rate of DLI formation has increased perhaps too dramatically. There are significant risks associated as well [7,9,23-27,29-31,33-40]. The most important message from this study is that the benefits of a DLI does not always outweigh the risks and perhaps too many people are getting DLIs when they don't need it. Platell et al. conducted a prospective observational study in 2005 and followed 233 patients at their center that underwent low or ultra-low anterior resections with DLI [27]. In this cohort, 16 (7%) of patients had an anastomotic leak, 7 (3%) were asymptomatic, and 9 (4%) required intervention; but only 2 (0.9%) patients required re-operation for their anastomotic leak [27]. The authors concluded that > 90% of their patient cohort had a DLI but did not benefit from it [27].

When analyzing the absolute risk reduction seen in this study, there is a 1% absolute risk reduction (ARR) of 90-day mortality in rectal cancer patients, a 2.3% ARR of 1-year mortality, and a 2.6% ARR of re-operation associated with DLIs. When this is converted to numbers

needed to treat, 100 rectal cancer patients would need to have a DLI to reduce one mortality at 90 days; 43 patients to decrease one mortality at 1 year; and 38 patients to decrease one re-operation at 30 days. For the patients that would not benefit from the DLI and are now exposed to the risks of DLIs, this can be a significant risk. Therefore, the next step is to determine who is at highest risk for anastomotic leak and only selectively utilize DLIs in that patient population.

In Nurkin et al.'s retrospective database analysis, patients with low pelvic anastomosis did not demonstrate benefit from their DLI but patients with coloanal anastomosis did worse without a DLI [26]. Therefore, the authors recommended DLIs for coloanal anastomosis. Shiomi et al. conducted a prospective observational study analyzing rates of AL with or without a diverting ostomy stratified by the level of anastomosis [79]. In this study, they identified that patients had significantly more leaks if their anastomosis was < 5cm from the anal verge. They also found that tumour size and the lack of a diverting ostomy were independently associated with risk of AL (ref). Therefore, they recommend DLI with any anastomosis < 5cm from the anal verge [79]. Zhang et al. conducted a multicenter analysis of risk factors for AL after middle or low rectal cancer resection [80]. All of their patients underwent rectal cancer resection without a diverting ostomy. Of those, 11.9% developed symptomatic class B or C AL. Of the patients that leaked, 55% required an operation [80]. They then analyzed a number of patient variables to determine which variables were associated with a higher risk of AL. The variables included: gender, age, history of diabetes, ASA classification, K-ras status of cancer, distance of tumor from anal verge ($> 7 \leq 10$ or ≤ 7 cm), histopathologic grade, TNM staging, tumor size (< 5cm or ≥ 5cm), preoperative chemoradiation therapy, BMI (< 25 or ≥ 25), hemoglobin level (≥ 110 or < 110), albumin level (≥ 35 or < 35), laparoscopic approach, operation time (≤ 180 mins or > 180 mins),

and blood loss (< 400mL or ≥ 400mL). Of those, male gender, distance of tumor from the anal verge ≤ 7 cm, preoperative chemoradiation therapy, K-ras mutation of the tumor, and diabetes mellitus were all significantly associated with a higher risk of leak. They also identified that male gender and blood loss ≥ 400mL was independently associated with AL requiring re-operation [80]. These factors identified should be utilized to develop an algorithm or scoring system to determine which patients should get a DLI.

Blok et al. conducted an interesting prospective cohort comparative trial to a historical control looking at morbidity after rectal cancer surgery [81]. One group is the historic group who routinely underwent laparoscopic low anterior resection with total mesorectal excision, stapled anastomosis and a DLI. The other group of patients all underwent a transanal total mesorectal excision, stapled anastomosis with suture re-enforcement, and highly selective use of DLIs. Overall, the historic group with routine use of DLIs stayed in hospital significantly longer [6 days (IQR 5-11 days) vs. 5 days (IQR 4-6 days); $p < 0.001$] [81]. There was no significant difference in overall complication, surgical complication, readmission rate, or re-intervention rate [81]. When they assessed ostomy specific outcomes, 80% of the highly selective group of patients never had a DLI vs. 8% in the other group ($p < 0.001$). The highly selective group also had significantly less total complications related to ostomies (13% vs 49%, $p < 0.001$), ostomy related readmissions (15% vs 84%, $p < 0.001$), and ostomy related reoperations (15% vs. 86%, p < 0.001) [81]. This study is not perfect – the patient cohorts had different types of surgeries, despite being similar demographically. However, it did demonstrate that patients' post-operative morbidity was not higher without a DLI and thus, highly selective use of DLIs is feasible.

4.8 Alternatives to defunctioning ileostomies

Other alternatives to a diverting ileostomy have been described in the literature. Two techniques described include the ghost ileostomy (GI) and endoluminal trans-anastomotic tube [82-86]. Ghost ileostomies have been previously described but are not currently a widely accepted practice. A GI is when a silastic band is placed around a loop of terminal ileum and the band is brought up through the abdominal wall and secured at the level of the skin (Figure 5) [82]. This allows surgeons the opportunity to mature a loop ileostomy locally, without having to perform a laparotomy if needed; but if no ileostomy is required, the silastic band can easily be removed, akin to removing a surgical drain [82]. In a study conducted by Miccini et al., when they described this technique, 11% of their cohort had their GI converted to a loop ileostomy due to diagnosis of anastomotic leak [82]. They reported no complications related to the GI and that maturing the ostomy was easy and safe [82]. Mori et al. conducted a retrospective cohort study evaluating the outcomes of using the technique of GIs and identified 168 patients that underwent total mesorectal excision (TME) with GI [83]. Twenty patients developed anastomotic leaks. In 13 of those patients, an ileostomy was fashioned under local anesthesia without the need for re-laparotomy [83]. The ileostomy led to resolution of the clinical signs of infection and closure of the anastomotic dehiscence. The only complication identified was that one patient had twisting of the ileal loop around the mesentery, resulting in bowel occlusion requiring reoperation [83]. Of the 168 patients that had a GI, 53 (91.2%) did not end up having an ileostomy. The authors of this study concluded that GIs, along with a highly selective stoma policy, would be a safe option for patients with low pelvic anastomoses [83].

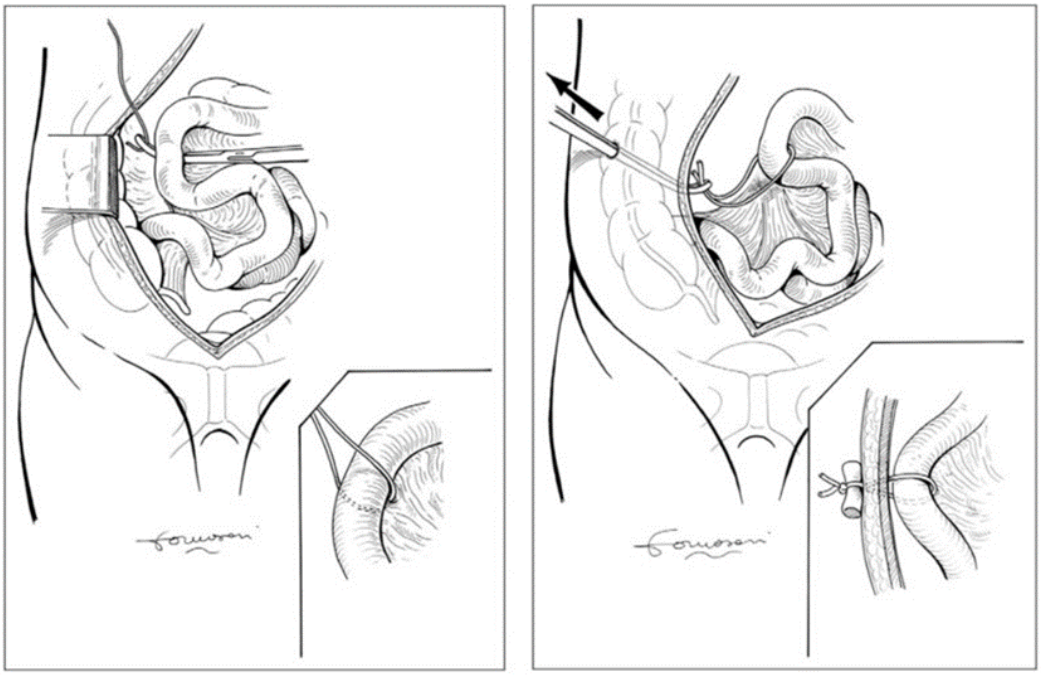

Figure 5. Ghost ileostomy

The second, less invasive, technique that has been described in the literature is leaving an endoluminal transanal tube in situ above the anastomosis after surgery [84-86]. Xiao et al. conducted a single institution RCT of patients undergoing low anterior resection for biopsy proven rectal cancer [84]. Patients were randomized to endoluminal tube (sutured in place and left for 5-7 days post-operatively) or no tube [84]. The primary outcome of interest was symptomatic AL. They found that patients in the endoluminal tube group had significantly fewer ALs as compared to patients in the control group (4.0% vs 9.6%, $p = 0.026$) [84]. Two other retrospective cohort studies have analyzed the efficacy of endoluminal transanal tubes [85,86]. In Hidaka et al.'s retrospective cohort study, 4.2% versus 13.8% of patients with and without a transanal tube had an AL, respectively ($p < 0.05$) [85]. Furthermore, the reoperation rate for symptomatic AL was 0% in the intervention group and 73.3% in the control group ($p < 0.05$) [85]. Yang's study did not demonstrate a significant difference between the rates of AL (9.8% vs

11.8%, $p = 0.652$), however, patients in the transanal tube group were significantly less likely to require reoperation for AL (2.9% vs 11.8%, $p = 0.016$) [86]. These studies suggest that a transanal rectal tube left in situ after low anterior resection is associated with decreased risk of reoperation for AL and may potentially decrease the overall risk of AL [84-86].

A third consideration, although not widely described and may be controversial, is to take a page from history and consider putting high risk patients on bowel rest and parenteral nutrition post-operatively. This was widely practiced historically with bowel resections before the advent of enhanced recovery after surgery (ERAS). Patients will be in hospital longer on index admission but would avoid the morbidities of a DLI as well as a second surgery of ileostomy reversal. Currently, there is no evidence for this proposed method but it would be an interesting option to explore.

Although the ghost ileostomy and transanal rectal tube approaches have not gained wide-spread popularity amongst surgeons, existing studies demonstrate promising results. Further investigations with Level I evidence should be pursued.

4.7 Limitations

As previously discussed, there was heterogeneity in the patient cohort, especially in the non-rectal cancer subgroup, which limits the definitive conclusions that can be made from the comparative analysis.

One of other biggest limitations of this study was the inability to detect ALs. Until recently, there was no specific code for AL. Therefore, documentation of AL in these administrative databases was not accurate. Attempts were made at combining different codes, such as the code of wound infection with percutaneous drainage or the code for wound infection combined with reoperation, but the results did not make clinical sense. This is the disadvantage of the administrative databases used for this study. A similar study conducted by Jafari et al. using the NSQIP database also could not report on anastomotic leak outcomes [31]. There was only one other retrospective database cohort study that was able to assess anastomotic leak and it was based on a prospectively maintained database in Japan [87]. Anastomotic leak is one of the most relevant clinical outcome measures when it comes to DLIs and not being able to accurately analyze its relationship to DLIs was a big limitation of this study.

Confounding by indication was a limitation of this retrospective study. Although we tried to control for multiple factors that may influence our outcomes, we still could not account for every single variable. For example, one important piece of information that we could not gather was the location of tumor in rectal cancer patients. There is strong evidence suggesting that low tumors and low anastomosis benefit from DLIs [10,26]. Therefore, surgeons would perform DLIs in patients with lower tumors. This inherently could have contributed to more morbidity outcomes that we could not adjust for.

At the onset of cohort identification, we set exclusion criteria that did exclude a number of patients from the overall cohort in an effort to decrease heterogeneity. A total of 6,675 patients met exclusion criteria and was eliminated from the patient cohort. Their missing data could have

confounded and added heterogeneity to the cohort but we also lost some information from these patients by excluding them.

Finally, majority of the codes used in the study were not validated. The codes chosen by the research group may not have been the most accurate codes to use, but majority of the outcomes assessed did not have associated validated codes. In situations where there were validated codes, such as with acute kidney injury, the validated codes were used.

4.8 Current recommendations & future directions

Currently, there are no defined guidelines on when it is appropriate to give patients a DLI. Textbooks provide little guidance and quote basic indications of DLIs as to divert the colon, to evacuate stool if the colon has been removed, or to relieve bowel obstruction [88]. However, little guidance is provided as to when it is appropriate to divert the colon, especially knowing that DLIs are not benign entities. In 2015, the American Society of Colorectal Surgeons (ASCRS) has a clinical guideline for ostomy surgery [89]. The guidelines recognize that there is significant morbidity associated with ostomies and provides evidence-based recommendations on how to fashion an ostomy to decrease morbidity. However, again, they do not provide any guidance on when it is appropriate to give a patient a DLI.

This current study has identified a benefit of DLIs in the rectal cancer patients with lower rates of reoperation and decreased mortality. As discussed, this likely correlates with previous studies demonstrating that DLIs are associated with decreased risk of clinically significant anastomotic leaks. This benefit, however, was not seen in the non-rectal cancer group. Other considerations

should be taken into account such as history of radiation therapy, level of tumor, and other patient baseline characteristics. It would be beneficial if surgical societies collated all available information on DLIs to produce a set of guidelines and criteria to assist surgeons in the decision making as to whether or not to give their patients a DLI.

There have been alternatives to long-term ileostomies that can be explored further. Some of these include early ileostomy reversal, ghost ileostomies (GI), and endoluminal trans-anastomotic tubes. There is evidence in the current literature demonstrating potential in these alternative techniques. These should be explored further in both clinical practice and clinical research.

Chapter V: Conclusion

A large population, real-life, retrospective patient cohort study was conducted to analyze the aggregate morbidity associated with defunctioning loop ileostomies. The only benefit seen associated with DLIs was a decrease in the risk of perioperative reoperation, 90-day mortality, and 1-year mortality in rectal cancer patients. There were significant complications associated with DLIs, including longer hospital length of stay and increased risk of major complication, acute kidney injury requiring hospitalization, hospital readmission, ventral hernia, and bowel obstruction, as well as a 13% permanent ostomy rate. There is certainly a role for DLIs to decrease risk of significant anastomotic leak requiring intervention and/or operation; however, DLIs are not benign entities. Based on the results of this study, it can be argued that highly selective utilization of DLIs should be recommended. We also observed an increasing trend of DLI utilization in the general surgery community. This trend should be questioned and scrutinized. Other factors should also be taken into consideration, such as patient comorbidities, age, and technical challenges during surgery.

What should be defined as “low” enough to quality for DLI warrants further investigation. It would also be beneficial if surgical societies collated information from all available evidence to come up with a guideline and possibly even a scoring system to guide surgeons in their clinical decision making.

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Appendix A

Appendix A Codes for low anterior resection, ileostomy, and ileostomy reversal

Codes for anterior resection

type	code	Fee Code Description
FEECODE	S171	INTESTINE-EXC-LT.HEMICOLECTOMY WITH ANT.RESECT/ANAST. ETC.
	S213	RECTUM-EXC.-PROCTECTOMY-ANTERIOR RESECT./PROCTOSIGMOIDECTOMY

INCODE	1NK77EN	Bypass with exteriorization, small intestine endoscopic [laparoscopic] approach end enterostomy (e.g. terminal, end or loop ileostomy)
	1NK77RR	Bypass with exteriorization, small intestine open approach end enterostomy (e.g. terminal, end or loop ileostomy)
	1NK77RRXXG	Bypass with exteriorization, small intestine open approach continent ileostomy using pedicled flap
	1NM87DE	Excision partial, large intestine endoscopic [laparoscopic, laparoscopic-assisted, hand-assisted] approach colorectal anastomosis technique
	1NM87DF	Excision partial, large intestine endoscopic [laparoscopic, laparoscopic-assisted, hand-assisted] approach colocolostomy anastomosis technique
	1NM87RD	Excision partial, large intestine open approach Colorectal anastomosis technique
	1NM87RN	Excision partial, large intestine open approach Colocolostomy anastomosis technique
	1NQ87DA	Excision partial, rectum endoscopic [laparoscopic, laparoscopic-assisted, hand-assisted] approach closure by apposition technique [e.g. suturing, stapling] or no closure required (for tissue regenerat
	1NQ87DE	Excision partial, rectum endoscopic [laparoscopic, laparoscopic-assisted, hand-assisted] approach colorectal anastomosis technique
	1NQ87DF	Excision partial, rectum endoscopic [laparoscopic] approach colorectal anastomosis technique
	1NQ87DX	Excision partial, rectum endoscopic [laparoscopic, laparoscopic-assisted, hand-assisted] approach stoma formation with distal closure
	1NQ87LA	Excision partial, rectum open abdominal [e.g. anterior] approach closure by apposition technique [e.g. suturing, stapling] or no closure required (for tissue regeneration)
	1NQ87RD	Excision partial, rectum open abdominal [e.g. anterior] approach colorectal anastomosis technique
	1NQ87TF	Excision partial, rectum open abdominal approach [e.g. anterior] stoma formation with distal closure
	1NQ89KZ	Excision total, rectum abdominoperineal approach coloanal anastomosis technique
	1NQ89KZXXG	Excision total, rectum abdominoperineal approach pouch formation
	1NQ89SF	Excision total, rectum abdominal [anterior] approach coloanal anastomosis technique
	1NQ89SFXXG	Excision total, rectum abdominal [anterior] approach pouch formation

PRCODE	6051	ANTERIOR RESECTION WITH CONCOMITANT COLOSTOMY
	6052	OTHER ANTERIOR RESECTION
	6053	POSTERIOR RESECTION
	6054	DUHAMEL RESECTION
	6055	HARTMANN RESECTION
	6059	OTHER RESECTION OF RECTUM NEC

Code for ileostomy

type	code	Fee Code Description
FEECODE	S149	INTESTINE-INC.-ENTEROTOMY-ILEOSTOMY

Codes for ileostomy reversal

type	code	Fee Code Description
FEECODE	S185	INTESTINE-SUT/CLOSURE-COLOSTOMY/ENTEROSTOMY-W/OUT RESEC/ANAS

INCODE	1NK82DP	Reattachment, small intestine endoscopic [laparoscopic] approach of enteroenterostomy [diversionary]
	1NK82EN	Reattachment, small intestine endoscopic [laparoscopic] approach of ileostomy
	1NK82RF	Reattachment, small intestine open approach of enteroenterostomy [diversionary]
	1NK82RR	Reattachment, small intestine open approach of ileostomy

PRCODE	5851	CLOSURE OF INTESTINAL STOMA, UNQUALIFIED
	5852	CLOSURE OF STOMA OF SMALL INTESTINE

Appendix B

Appendix B. Definitions of patient demographics and source of information

Variable	Data Sources	Window	Reporting Detail
Patient Variables			
Patient Age	RPDB	Indexdt	Mean (SD), Median (IQR)
Patient Sex	RPDB	Indexdt	N (%) each category
Income quintile	RPDB	Indexdt	N (%) each quintile
Patient LHIN	RPDB	Indexdt	N (%) each category
Rurality (rural vs. urban)	RPDB	Indexdt	N (%) rural, urban, missing
ACG RUG	DAD/SDS/NACRS/OHIP	Indexdt – 2 years to index admdate – 1 day (18-mo lookback for NACRS)	N (%) low (RUB = 0-3), moderate (RUB = 4), high (RUB = 5)
Rectal Cancer	OCR	From inception of data to indexdt + 90 days	N (%)
Cancer Stage	OCR	n/a	N (%) 0, 1, 2, 3, 4
Hx of radiotherapy	OHIP	Indexdt – 120 days to indexdt	N (%)
Hx of chemotherapy	OHIP	Indexdt – 120 days to indexdt	N (%)
Procedure, Institution, and Surgeon Variables			
Surgical approach	DAD	Index date	N (%) open, laparoscopic
ASA 3-to-5	OHIP	Index date	N (%) yes
Institution teaching status (Academic vs. non-academic)	DAD/SDS	--	N (%) academic
Surgeon age	IPDB	Index date	Mean (SD), Median (IQR)
Surgeon annual anterior resection volume	OHIP	Fiscal year of the indexdt	Mean (SD), Median (IQR)
Fiscal year	DAD/SDS	Index date	N (%) each year

Appendix C

Appendix C. Other Codes

type	code	description
DX10CODE	N17	Acute renal failure
	N170	Acute renal failure with tubular necrosis
	N171	Acute renal failure with acute cortical necrosis
	N172	Acute renal failure with medullary necrosis
	N178	Other acute renal failure
	N179	Acute renal failure, unspecified

DXCODE	5845	LOWER NEPHRON NEPHROSIS
	5846	AC RENAL FAIL, CORT NECR
	5847	AC REN FAIL, MEDULL NECR
	5848	AC RENAL FAILURE NEC
	5849	ACUTE RENAL FAILURE NOS

Acute renal failure codes

type	code	Fee Code Description
FEECODE	G093	Haemodiafiltration - Contin. Init & Acute (repeatx3)
	G095	Slow Continuous Ultra Filtration - Initial & Acute (repeat)
	G294	ARTERIOVENOUS SLOW CONT. ULTRAFILTRATN-INIT& ACUTE
	G295	CONT. ARTERIOVENOUS HAEMOFILTRAT'N - INIT. & AC. (MAX 3)
	G323	D./T. PROC.-DIALYSIS-HAEMODIALYSIS-ACUTE,REPEAT
	G330	D./T. PROC.-DIALYSIS-PERITONEAL-ACUTE (UP TO 48 HRS)
	G331	D./T. PROC.-DIALYSIS-PERITONEAL-REPEAT ACUTE (UP TO 48 HRS)
	G866	INTERMITTENT HEMODIAL AUX TREAT CTRE(PER TREAT)
	R849	D./T. PROC.-DIALYSIS-HEMO-INITIAL AND ACUTE

Dialysis codes

type	code	Fee Code Description
FEECODE	E016	PATIENTS ASA 5 - MORIBUND PT NOT EXPECTED TO LIVE
	E017	PATIENTS ASA 4 - PATIENT WITH INCAPACITATING
	E022	PATIENTS ASA 3

ASA codes

type	code	Description of this dxcode suffix type combination
DX10CODE	E1020	Type 1 diabetes mellitus with incipient diabetic nephropathy
	E10200	Type 1 diabetes mellitus with incipient diabetic nephropathy, adequately controlled with diet or oral agent
	E10201	Type 1 diabetes mellitus with incipient diabetic nephropathy, adequately controlled with insulin
	E10202	Type 1 diabetes mellitus with incipient diabetic nephropathy, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E10203	Type 1 diabetes mellitus with incipient diabetic nephropathy, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E10204	Type 1 diabetes mellitus with incipient diabetic nephropathy, inadequately controlled with insulin
	E10209	Type 1 diabetes mellitus with incipient diabetic nephropathy, level of control unspecified
	E1021	Type 1 diabetes mellitus with established diabetic nephropathy
	E10210	Type 1 diabetes mellitus with established diabetic nephropathy, adequately controlled with diet or oral agent
	E10211	Type 1 diabetes mellitus with established diabetic nephropathy, adequately controlled with insulin
	E10212	Type 1 diabetes mellitus with established diabetic nephropathy, inadequately controlled with diet or oral agents (and insulin not used to stablize)
	E10213	Type 1 diabetes mellitus with established diabetic nephropathy, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E10214	Type 1 diabetes mellitus with established diabetic nephropathy, inadequately controlled with insulin
	E10219	Type 1 diabetes mellitus with established diabetic nephropathy, level of control unspecified
	E1022	Type 1 diabetes mellitus with end-stage renal disease [ESRD]
	E10220	Type 1 diabetes mellitus with end-stage renal disease [ESRD], adequately controlled with diet or oral agents
	E10221	Type 1 diabetes mellitus with end-stage renal disease [ESRD], adequately controlled with insulin
	E10222	Type 1 diabetes mellitus with end stage renal disease [ESRD], inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E10223	Type 1 diabetes mellitus with end stage renal disease [ESRD], inadequately controlled with diet or oral agents but adequately controlled with insulin
	E10224	Type 1 diabetes mellitus with end stage renal disease [ESRD], inadequately controlled with insulin
	E10229	Type 1 diabetes mellitus with end stage renal disease [ESRD], level of control unspecified
	E1023	Type 1 diabetes mellitus with established or advanced kidney disease
	E1028	Type 1 diabetes mellitus with other specified kidney complication not elsewhere classified
	E10280	Type 1 diabetes mellitus with other specified renal complication, adequately controlled with diet or oral agents
	E10281	Type 1 diabetes mellitus with other specified renal complication, adequately controlled with insulin
	E10282	Type 1 diabetes mellitus with other specified renal complication, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E10283	Type 1 diabetes mellitus with other specified renal complication, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E10284	Type 1 diabetes mellitus with other specified renal complication, inadequately controlled with insulin
	E10289	Type 1 diabetes mellitus with other specified renal complication, level of control unspecified
	E10290	Type 1 diabetes mellitus with renal complication unspecified, adequately controlled with diet or oral agents
	E10291	Type 1 diabetes mellitus with renal complication unspecified, adequately controlled with insulin
	E10292	Type 1 diabetes mellitus with renal complication unspecified, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E10293	Type 1 diabetes mellitus with renal complication unspecified, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E10294	Type 1 diabetes mellitus with renal complication unspecified, inadequately controlled with insulin
	E10299	Type 1 diabetes mellitus with renal complication unspecified, level of control unspecified
	E1120	Type 2 diabetes mellitus with incipient diabetic nephropathy
	E11200	Type 2 diabetes mellitus with incipient diabetic nephropathy, adequately controlled with diet or oral agents
	E11201	Type 2 diabetes mellitus with incipient diabetic nephropathy, adequately controlled with insulin
	E11202	Type 2 diabetes mellitus with incipient diabetic nephropathy, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E11203	Type 2 diabetes mellitus with incipient diabetic nephropathy, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E11204	Type 2 diabetes mellitus with incipient diabetics nephropathy, inadequately controlled with insulin
	E11209	Type 2 diabetes mellitus with incipient diabetics nephropathy, level of control unspecified

	E1121	Type 2 diabetes mellitus with established diabetic nephropathy
	E11210	Type 2 diabetes mellitus with established diabetic nephropathy, adequately controlled with diet or oral agents
	E11211	Type 2 diabetes mellitus with established diabetic nephropathy, adequately controlled with insulin
	E11212	Type 2 diabetes mellitus with established diabetic nephropathy, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E11213	Type 2 diabetes mellitus with established diabetic nephropathy, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E11214	Type 2 diabetes mellitus with established diabetic nephropathy, inadequately controlled with insulin
	E11219	Type 2 diabetes mellitus with established diabetic nephropathy, level of control unspecified
	E1122	Type 2 diabetes mellitus with end-stage renal disease [ESRD]
	E11220	Type 2 diabetes mellitus with end-stage renal disease [ESRD], adequately controlled with diet or oral agents
	E11221	Type 2 diabetes mellitus with end-stage renal disease [ESRD], adequately controlled with insulin
	E11222	Type 2 diabetes mellitus with end-stage renal disease [ESRD], inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E11223	Type 2 diabetes mellitus with end-stage renal disease [ESRD], inadequately controlled with diet or oral agents but adequately controlled with insulin
	E11224	Type 2 diabetes mellitus with end-stage renal disease [ESRD], inadequately controlled with insulin
	E11229	Type 2 diabetes mellitus with end-stage renal disease [ESRD] ,level of control unspecified
	E1123	Type 2 diabetes mellitus with established or advanced kidney disease
	E1128	Type 2 diabetes mellitus with other specified kidney complication not elsewhere classified
	E11280	Type 2 diabetes mellitus with other specified renal complication, adequately controlled with diet or oral agents
	E11281	Type 2 diabetes mellitus with other specified renal complication, adequately controlled with insulin
	E11282	Type 2 diabetes mellitus with other specified renal complication, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E11283	Type 2 diabetes mellitus with other specified renal complication, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E11284	Type 2 diabetes mellitus with other specified renal complication, inadequately controlled with insulin
	E11289	Type 2 diabetes mellitus with other specified renal complication, level of control unspecified
	E11290	Type 2 diabetes mellitus with renal complication unspecified, adequately controlled with diet or oral agents
	E11291	Type 2 diabetes mellitus with renal complication unspecified, adequately controlled with insulin
	E11292	Type 2 diabetes mellitus with renal complication unspecified, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E11293	Type 2 diabetes mellitus with renal complication unspecified, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E11294	Type 2 diabetes mellitus with renal complication unspecified, inadequately controlled with insulin
	E11299	Type 2 diabetes mellitus with renal complication unspecified, level of control unspecified
	E1320	Other specified diabetes mellitus with incipient diabetic nephropathy
	E13200	Other specified diabetes mellitus with incipient diabetic nephropathy, adequately controlled with diet or oral agents
	E13201	Other specified diabetes mellitus with incipient diabetic nephropathy, adequately controlled with insulin
	E13202	Other specified diabetes mellitus with incipient diabetic nephropathy, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E13203	Other specified diabetes mellitus with incipient diabetic nephropathy, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E13204	Other specified diabetes mellitus with incipient diabetic nephropathy, inadequately controlled with insulin
	E13209	Other specified diabetes mellitus with incipient diabetic nephropathy, level of control unspecified
	E1321	Other specified diabetes mellitus with established diabetic nephropathy
	E13210	Other specified diabetes mellitus with established diabetic nephropathy, adequately controlled with diet or oral agents
	E13211	Other specified diabetes mellitus with established diabetic nephropathy, adequately controlled with insulin
	E13212	Other specified diabetes mellitus with established diabetic nephropathy, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E13213	Other specified diabetes mellitus with established diabetic nephropathy, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E13214	Other specified diabetes mellitus with established diabetic nephropathy, inadequately controlled with insulin
	E13219	Other specified diabetes mellitus with established diabetic nephropathy, level of control unspecified
	E1322	Other specified diabetes mellitus with end-stage renal disease [ESRD]
	E13220	Other specified diabetes mellitus with end-stage renal disease [ESRD], adequately controlled with diet or oral agents

	E13221	Other specified diabetes mellitus with end-stage renal disease [ESRD], adequately controlled with insulin
	E13222	Other specified diabetes mellitus with end-stage renal disease [ESRD], inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E13223	Other specified diabetes mellitus with end-stage renal disease [ESRD], inadequately controlled with diet or oral agents but adequately controlled with insulin
	E13224	Other specified diabetes mellitus with end-stage renal disease [ESRD], inadequately controlled with insulin
	E13229	Other specified diabetes mellitus with end-stage renal disease [ESRD] ,level of control unspecified
	E1323	Other specified diabetes mellitus with established or advanced kidney disease
	E1328	Other specified diabetes mellitus with other specified kidney complication not elsewhere classified
	E13280	Other specified diabetes mellitus with other specified renal complication, adequately controlled with diet or oral agents
	E13281	Other specified diabetes mellitus with other specified renal complication, adequately controlled wtih insulin
	E13282	Other specified diabetes mellitus with other specified renal complication, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E13283	Other specified diabetes mellitus with other specified renal complication, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E13284	Other specified diabetes mellitus with other specified renal complication, inadequately controlled with insulin
	E13289	Other specified diabetes mellitus with other specified renal complication, level of control unspecified
	E13290	Other specified diabetes mellitus with renal complication unspecified, adequately controlled with diet or oral agents
	E13291	Other specified diabetes mellitus with renal complication unspecified, adequately controlled with insulin
	E13292	Other specified diabetes mellitus with renal complication unspecified, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E13293	Other specified diabetes mellitus with renal complication unspecified, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E13294	Other specified diabetes mellitus with renal complication unspecified, inadequately controlled with insulin
	E13299	Other specified diabetes mellitus with renal complication unspecified, level of control unspecified
	E1420	Unspecified diabetes mellitus with incipient diabetic nephropathy
	E14200	Unspecified diabetes mellitus with incipient diabetic nephropathy, adequately controlled with diet or oral agents
	E14201	Unspecified diabetes mellitus with incipient diabetic nephropathy, adequately controlled with insulin
	E14202	Unspecified diabetes mellitus with incipient diabetic nephropathy, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E14203	Unspecified diabetes mellitus with incipient diabetic nephropathy, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E14204	Unspecified diabetes mellitus with incipient diabetic nephropathy, inadequately controlled with insulin
	E14209	Unspecified diabetes mellitus with incipient diabetic nephropathy, level of control unspecified
	E1421	Unspecified diabetes mellitus with established diabetic nephropathy
	E14210	Unspecified diabetes mellitus with established diabetic nephropathy, adequately controlled with diet or oral agents
	E14211	Unspecified diabetes mellitus with established diabetic nephropathy, adequately controlled with insulin
	E14212	Unspecified diabetes mellitus with established diabetic nephropathy, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E14213	Unspecified diabetes mellitus with established diabetic nephropathy, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E14214	Unspecified diabetes mellitus with established diabetic nephropathy, inadequately controlled with insulin
	E14219	Unspecified diabetes mellitus with established diabetic nephropathy, level of control unspecified
	E1422	Unspecified diabetes mellitus with end-stage renal disease [ESRD]
	E14220	Unspecified diabetes mellitus with end-stage renal disease [ESRD], adequately controlled with diet or oral agents
	E14221	Unspecified diabetes mellitus with end-stage renal disease [ESRD], adequately controlled with insulin
	E14222	Unspecified diabetes mellitus with end-stage renal disease [ESRD], inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E14223	Unspecified diabetes mellitus with end-stage renal disease [ESRD], inadequately controlled with diet or oral agents but adequately controlled with insulin
	E14224	Unspecified diabetes mellitus with end-stage renal disease [ESRD], inadequately controlled with insulin
	E14229	Unspecified diabetes mellitus with end-stage renal disease [ESRD], level of control unspecified
	E1423	Unspecified diabetes mellitus with established or advanced kidney disease
	E1428	Unspecified diabetes mellitus with other specified kidney complication not elsewhere classified
	E14280	Unspecified diabetes mellitus with other specified renal complication ,adequately controlled with diet or oral agents
	E14281	Unspecified diabetes mellitus with other specified renal complication ,adequately controlled with insulin

	E14282	Unspecified diabetes mellitus with other specified renal complication, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E14283	Unspecified diabetes mellitus with other specified renal complication, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E14284	Unspecified diabetes mellitus with other specified renal complication, inadequately controlled with insulin
	E14289	Unspecified diabetes mellitus with other specified renal complication, level of control unspecified
	E14290	Unspecified diabetes mellitus with renal complication unspecified, adequately controlled with diet or oral agents
	E14291	Unspecified diabetes mellitus with renal complication unspecified, adequately controlled with insulin
	E14292	Unspecified diabetes mellitus with renal complication unspecified, inadequately controlled with diet or oral agents (and insulin not used to stabilize)
	E14293	Unspecified diabetes mellitus with renal complication unspecified, inadequately controlled with diet or oral agents but adequately controlled with insulin
	E14294	Unspecified diabetes mellitus with renal complication unspecified, inadequately controlled with insulin
	E14299	Unspecified diabetes mellitus with renal complication unspecified, level of control unspecified
	I12	Hypertensive renal disease
	I13	Hypertensive heart and renal disease
	N00	Acute nephritic syndrome
	N000	Acute nephritic syndrome, minor glomerular abnormality
	N001	Acute nephritic syndrome, focal and segmental glomerular lesions
	N002	Acute nephritic syndrome, diffuse membranous glomerulonephritis
	N003	Acute nephritic syndrome, diffuse mesangial proliferative glomerulonephritis
	N004	Acute nephritic syndrome, diffuse endocapillary proliferative glomerulonephritis
	N005	Acute nephritic syndrome, diffuse mesangiocapillary glomerulonephritis
	N006	Acute nephritic syndrome, dense deposit disease
	N007	Acute nephritic syndrome, diffuse crescentic glomerulonephritis
	N008	Acute nephritic syndrome, other
	N009	Acute nephritic syndrome, unspecified
	N01	Rapidly progressive nephritic syndrome
	N010	Rapidly progressive nephritic syndrome, minor glomerular abnormality
	N011	Rapidly progressive nephritic syndrome, focal and segmental glomerular lesions
	N012	Rapidly progressive nephritic syndrome, diffuse membranous glomerulonephritis
	N013	Rapidly progressive nephritic syndrome, diffuse mesangial proliferative glomerulonephritis
	N014	Rapidly progressive nephritic syndrome, diffuse endocapillary proliferative glomerulonephritis
	N015	Rapidly progressive nephritic syndrome, diffuse mesangiocapillary glomerulonephritis
	N016	Rapidly progressive nephritic syndrome, dense deposit disease
	N017	Rapidly progressive nephritic syndrome, diffuse crescentic glomerulonephritis
	N018	Rapidly progressive nephritic syndrome, other
	N019	Rapidly progressive nephritic syndrome, unspecified
	N02	Recurrent and persistent haematuria
	N020	Recurrent and persistent haematuria, minor glomerular abnormality
	N021	Recurrent and persistent haematuria, focal and segmental glomerular lesions
	N022	Recurrent and persistent haematuria, diffuse membranous glomerulonephritis
	N023	Recurrent and persistent haematuria, diffuse mesangial proliferative glomerulonephritis
	N024	Recurrent and persistent haematuria, diffuse endocapillary proliferative glomerulonephritis
	N025	Recurrent and persistent haematuria, diffuse mesangiocapillary glomerulonephritis
	N026	Recurrent and persistent haematuria, dense deposit disease
	N027	Recurrent and persistent haematuria, diffuse crescentic glomerulonephritis
	N028	Recurrent and persistent haematuria, other
	N029	Recurrent and persistent haematuria, unspecified
	N03	Chronic nephritic syndrome
	N030	Chronic nephritic syndrome, minor glomerular abnormality
	N031	Chronic nephritic syndrome, focal and segmental glomerular lesions
	N032	Chronic nephritic syndrome, diffuse membranous glomerulonephritis

	N033	Chronic nephritic syndrome, diffuse mesangial proliferative glomerulonephritis
	N034	Chronic nephritic syndrome, diffuse endocapillary proliferative glomerulonephritis
	N035	Chronic nephritic syndrome, diffuse mesangiocapillary glomerulonephritis
	N036	Chronic nephritic syndrome, dense deposit disease
	N037	Chronic nephritic syndrome, diffuse crescentic glomerulonephritis
	N038	Chronic nephritic syndrome, other
	N039	Chronic nephritic syndrome, unspecified
	N04	Nephrotic syndrome
	N040	Nephrotic syndrome, minor glomerular abnormality
	N041	Nephrotic syndrome, focal and segmental glomerular lesions
	N042	Nephrotic syndrome, diffuse membranous glomerulonephritis
	N043	Nephrotic syndrome, diffuse mesangial proliferative glomerulonephritis
	N044	Nephrotic syndrome, diffuse endocapillary proliferative glomerulonephritis
	N045	Nephrotic syndrome, diffuse mesangiocapillary glomerulonephritis
	N046	Nephrotic syndrome, dense deposit disease
	N047	Nephrotic syndrome, diffuse crescentic glomerulonephritis
	N048	Nephrotic syndrome, other
	N049	Nephrotic syndrome, unspecified
	N05	Unspecified nephritic syndrome
	N050	Unspecified nephritic syndrome, minor glomerular abnormality
	N051	Unspecified nephritic syndrome, focal and segmental glomerular lesions
	N052	Unspecified nephritic syndrome, diffuse membranous glomerulonephritis
	N053	Unspecified nephritic syndrome, diffuse mesangial proliferative glomerulonephritis
	N054	Unspecified nephritic syndrome, diffuse endocapillary proliferative glomerulonephritis
	N055	Unspecified nephritic syndrome, diffuse mesangiocapillary glomerulonephritis
	N056	Unspecified nephritic syndrome, dense deposit disease
	N057	Unspecified nephritic syndrome, diffuse crescentic glomerulonephritis
	N058	Unspecified nephritic syndrome, other
	N059	Unspecified nephritic syndrome, unspecified
	N06	Isolated proteinuria with specified morphological lesion
	N060	Isolated proteinuria with minor glomerular abnormality
	N061	Isolated proteinuria with focal and segmental glomerular lesions
	N062	Isolated proteinuria with diffuse membranous glomerulonephritis
	N063	Isolated proteinuria with diffuse mesangial proliferative glomerulonephritis
	N064	Isolated proteinuria with diffuse endocapillary proliferative glomerulonephritis
	N065	Isolated proteinuria with diffuse mesangiocapillary glomerulonephritis
	N066	Isolated proteinuria with dense deposit disease
	N067	Isolated proteinuria with diffuse crescentic glomerulonephritis
	N068	Isolated proteinuria with specified morphological lesion, other
	N069	Isolated proteinuria with specified morphological lesion, unspecified
	N07	Hereditary nephropathy, not elsewhere classified
	N070	Hereditary nephropathy, not elsewhere classified, minor glomerular abnormality
	N071	Hereditary nephropathy, not elsewhere classified, focal and segmental glomerular lesions
	N072	Hereditary nephropathy, not elsewhere classified, diffuse membranous glomerulonephritis
	N073	Hereditary nephropathy, not elsewhere classified, diffuse mesangial proliferative glomerulonephritis
	N074	Hereditary nephropathy, not elsewhere classified, diffuse endocapillary proliferative glomerulonephritis
	N075	Hereditary nephropathy, not elsewhere classified, diffuse mesangiocapillary glomerulonephritis
	N076	Hereditary nephropathy, not elsewhere classified, dense deposit disease
	N077	Hereditary nephropathy, not elsewhere classified, diffuse crescentic glomerulonephritis
	N078	Hereditary nephropathy, not elsewhere classified, other
	N079	Hereditary nephropathy, not elsewhere classified, unspecified

	N08	Glomerular disorders in diseases classified elsewhere
	N080	Glomerular disorders in infectious and parasitic diseases classified elsewhere
	N081	Glomerular disorders in neoplastic diseases
	N082	Glomerular disorders in blood diseases and disorders involving the immune mechanism
	N083	Glomerular disorders in diabetes mellitus
	N0831	Glomerular disorders in diabetes mellitus, chronic kidney disease, stage 1
	N0832	Glomerular disorders in diabetes mellitus, chronic kidney disease, stage 2
	N0833	Glomerular disorders in diabetes mellitus, chronic kidney disease, stage 3
	N0834	Glomerular disorders in diabetes mellitus, chronic kidney disease, stage 4
	N0835	Glomerular disorders in diabetes mellitus, chronic kidney disease, stage 5
	N0838	Other glomerular disorders in diabetes mellitus
	N0839	Unspecified glomerular disorders in diabetes mellitus
	N084	Glomerular disorders in other endocrine, nutritional and metabolic diseases
	N085	Glomerular disorders in systemic connective tissue disorders
	N088	Glomerular disorders in other diseases classified elsewhere
	N10	Acute tubulo-interstitial nephritis
	N11	Chronic tubulo-interstitial nephritis
	N110	Nonobstructive reflux-associated chronic pyelonephritis
	N111	Chronic obstructive pyelonephritis
	N118	Other chronic tubulo-interstitial nephritis
	N119	Chronic tubulo-interstitial nephritis, unspecified
	N12	Tubulo-interstitial nephritis, not specified as acute or chronic
	N13	Obstructive and reflux uropathy
	N130	Hydronephrosis with ureteropelvic junction obstruction
	N131	Hydronephrosis with ureteral stricture, not elsewhere classified
	N132	Hydronephrosis with renal and ureteral calculous obstruction
	N133	Other and unspecified hydronephrosis
	N134	Hydroureter
	N135	Kinking and stricture of ureter without hydronephrosis
	N136	Pyonephrosis
	N137	Vesicoureteral-reflux-associated uropathy
	N138	Other obstructive and reflux uropathy
	N139	Obstructive and reflux uropathy, unspecified
	N14	Drug- and heavy-metal-induced tubulo-interstitial and tubular conditions
	N140	Analgesic nephropathy
	N141	Nephropathy induced by other drugs, medicaments and biological substances
	N142	Nephropathy induced by unspecified drug, medicament or biological substance
	N143	Nephropathy induced by heavy metals
	N144	Toxic nephropathy, not elsewhere classified
	N15	Other renal tubulo-interstitial diseases
	N150	Balkan nephropathy
	N151	Renal and perinephric abscess
	N158	Other specified renal tubulo-interstitial diseases
	N159	Renal tubulo-interstitial disease, unspecified
	N16	Renal tubulo-interstitial disorders in diseases classified elsewhere
	N160	Renal tubulo-interstitial disorders in infectious and parasitic diseases classified elsewhere
	N161	Renal tubulo-interstitial disorders in neoplastic diseases
	N162	Renal tubulo-interstitial disorders in blood diseases and disorders involving the immune mechanism
	N163	Renal tubulo-interstitial disorders in metabolic diseases
	N164	Renal tubulo-interstitial disorders in systemic connective tissue disorders
	N165	Renal tubulo-interstitial disorders in transplant rejection

	N168	Renal tubulo-interstitial disorders in other diseases classified elsewhere
	N17	Acute renal failure
	N170	Acute renal failure with tubular necrosis
	N171	Acute renal failure with acute cortical necrosis
	N172	Acute renal failure with medullary necrosis
	N178	Other acute renal failure
	N179	Acute renal failure, unspecified
	N18	Chronic renal failure
	N180	End-stage renal disease
	N181	Chronic kidney disease, stage 1
	N182	Chronic kidney disease, stage 2
	N183	Chronic kidney disease, stage 3
	N184	Chronic kidney disease, stage 4
	N185	Chronic kidney disease, stage 5
	N188	Other chronic renal failure
	N189	Chronic kidney disease, unspecified
	N19	Unspecified kidney failure
	N20	Calculus of kidney and ureter
	N200	Calculus of kidney
	N201	Calculus of ureter
	N202	Calculus of kidney with calculus of ureter
	N209	Urinary calculus, unspecified
	N21	Calculus of lower urinary tract
	N210	Calculus in bladder
	N211	Calculus in urethra
	N218	Other lower urinary tract calculus
	N219	Calculus of lower urinary tract, unspecified
	N22	Calculus of urinary tract in diseases classified elsewhere
	N220	Urinary calculus in schistosomiasis [bilharziasis]
	N228	Calculus of urinary tract in other diseases classified elsewhere
	N23	Unspecified renal colic

DXCODE	2504	DIAB RENAL MANIF ADULT
	25040	DIAB RENAL MANIF ADULT
	25041	DIAB RENAL MANIF JUVEN
	4030	MAL HYPERTENS RENAL DIS NO RF
	40300	MAL HYPERTENS RENAL DIS NO RF
	40301	MAL HYPERTENS RENAL DISEASE W RF
	4031	BEN HYPERTENS RENAL DISEASE NO RF
	40310	BEN HYPERTENS RENAL DISEASE NO RF
	40311	BEN HYPERTENS RENAL DISEASE W RF
	4039	HYPERTENS RENAL DIS NOS NO RF
	40390	HYPERTENS RENAL DIS NOS NO RF
	40391	HYPERTENS RENAL DIS NOS W RF
	4040	MAL HYPER HRT/REN DIS NO CHF/RF
	40400	MAL HYPER HRT/REN DIS NO CHF/RF
	40401	MAL HYPERTENS HRT/REN W CHF
	40402	MAL HYPERTENS HRT/REN W RF
	40403	MAL HYPER HRT/REN DIS W CHF/RF
	4041	BEN HYPER HRT/REN DIS NO CHF/RF
	40410	BEN HYPER HRT/REN DIS NO CHF/RF

	40411	BEN HYPERTENS HRT/REN DIS W CHF
	40412	BEN HYPERTENS HRT/REN DIS W RF
	40413	BEN HYPER HRT/REN DIS W CHF/RF
	4049	HYPER HRT/REN DIS NOS NO CHF/RF
	40490	HYPER HRT/REN DIS NOS NO CHF/RF
	40491	HYPERTENS HRT/REN DIS NOS W CHF
	40492	HYPERTENS HRT/REN DIS NOS W RF
	40493	HYPER HRT/REN DIS NOS W CHF/RF
	5830	PROLIFERAT NEPHRITIS NOS
	5831	MEMBRANOUS NEPHRITIS NOS
	5832	MEMBRANOPROLIF NEPHR NOS
	5834	RAPIDLY PROG NEPHRIT NOS
	5836	RENAL CORT NECROSIS NOS
	5837	NEPHR NOS/MEDULL NECROS
	5838	NEPHRITIS NOS IN OTH DIS
	58381	NEPHRITIS NOS IN OTH DIS
	58389	NEPHRITIS NEC
	5839	NEPHRITIS NOS
	5845	LOWER NEPHRON NEPHROSIS
	5846	AC RENAL FAIL, CORT NECR
	5847	AC REN FAIL, MEDULL NECR
	5848	AC RENAL FAILURE NEC
	5849	ACUTE RENAL FAILURE NOS
	585	CHRONIC RENAL FAILURE
	5850	CHRONIC RENAL FAILURE
	586	RENAL FAILURE NOS
	5860	RENAL FAILURE NOS
	5888	IMPAIRED RENAL FUNCT NEC
	5889	IMPAIRED RENAL FUNCT NOS
	5920	CALCULUS OF KIDNEY
	5921	CALCULUS OF URETER
	5929	URINARY CALCULUS NOS
	5939	RENAL URETERAL DIS NOS

OHIPDX	403	Hypertensive renal disease
	585	Chronic renal failure, uremia

Chronic kidney disease codes

type	code	description
INCODE	1NQ87DA	Excision partial, rectum endoscopic [laparoscopic, laparoscopic-assisted, hand-assisted] approach closure by apposition technique [e.g. suturing, stapling] or no closure required (for tissue regeneration)
	1NQ87DE	Excision partial, rectum endoscopic [laparoscopic, laparoscopic-assisted, hand-assisted] approach colorectal anastomosis technique
	1NQ87DX	Excision partial, rectum endoscopic [laparoscopic, laparoscopic-assisted, hand-assisted] approach stoma formation with distal closure

Laparoscopy codes

type	code	Fee Code Description
FEECODE	X310	TREATMENT PLANNING LEVEL 1
	X311	TREATMENT PLANNING LEVEL 2
	X312	TREATMENT PLANNING LEVEL 3
	X313	TREATMENT PLANNING LEVEL 4
	X322	THERA. RADIOL.-RADIUM-SEALED SOURCE-TREAT. PLANNING

Radiation therapy codes

type	code	Fee Code Description
FEECODE	G281	D./T. PROC.INJ/INF-INTRAVEN-CHEMOTHERAPY-EA.ADD.INJ.TO G381
	G339	Chemotherapy - Single agent intravenous chemotherapy i.e. doxorubicin, daunorubicin, epirubicin, mitoxintrone, cisplatin or bleomycin (greater than 10 units per metre square)
	G345	D&T MULT.AGENTS CHEMOTHER.GREATER THAN 10 UNITS PER MET.SQ.
	G359	D&T SING.AGENT CHEMOTHER.(GREATER THAN 2G/M2 OR 1G/M2.)
	G381	D./T. PROC. INJECT/INFUS. INTRAVENOUS CHEMOTHERAPY-1ST INJ

Chemotherapy codes

type	code	description
DX10CODE	C20	Malignant neoplasm of rectum

Rectal cancer code

Appendix D

Appendix D. Definition of outcomes and sources of information

Variable	Data Sources	Window	Reporting Detail
30-day mortality	RPDB	Indexdt to Indexdt + 30 days	N (%) yes
90-day mortality	RPDB	Indexdt to indexdt + 90 days	N (%) yes
1-year mortality	RPDB	Indexdt to indexdt + 365 days	N (%) yes
Re-operation	DAD/SDS OHIP	Indexdt +1 day to indexdt + 30 days	N (%) yes
Major complication	DAD/OHIP	Indexdt to indexdt + 30 days	N (%) yes
Re-admission	DAD	ddate to ddate +30 days	N (%) yes
Hospital length of stay	DAD	--	Mean (SD) Median (IQR)
Acute renal failure requiring hospitalization	DAD	Indexdt to Indexdt + 180 days	N (%) yes
Ventral hernia	DAD/SDS	Indexdt to Indexdt + 180 days	N (%) yes
Bowel obstruction	DAD/SDS	Indexdt to Indexdt + 180 days	N (%) yes
Bleeding	DAD/SDS	Indexdt to Indexdt + 30 days	N (%) yes
Deep space infection	DAD/SDS	Indexdt + 30 days Dt reversal + 30 days	N (%) yes N (%) yes
Parastomal hernia	DAD/SDS		
Enterocutaneous fistula	DAD/SDS		N (%) yes
Hospital length of stay			
Number of days spent in hospital			

Appendix E

Appendix E. Outcome codes

type	code	description
DX10CODE	N17	Acute renal failure
	N170	Acute renal failure with tubular necrosis
	N171	Acute renal failure with acute cortical necrosis
	N172	Acute renal failure with medullary necrosis
	N178	Other acute renal failure
	N179	Acute renal failure, unspecified

DXCODE	5845	LOWER NEPHRON NEPHROSIS
	5846	AC RENAL FAIL, CORT NECR
	5847	AC REN FAIL, MEDULL NECR
	5848	AC RENAL FAILURE NEC
	5849	ACUTE RENAL FAILURE NOS

Codes for acute kidney injury

type	code	Fee Code Description
FEECODE	G093	Haemodiafiltration - Contin. Init & Acute (repeatx3)
	G095	Slow Continuous Ultra Filtration - Initial & Acute (repeat)
	G294	ARTERIOVENOUS SLOW CONT. ULTRAFILTRATN-INIT& ACUTE
	G295	CONT. ARTERIOVENOUS HAEMOFILTRAT'N - INIT. & AC. (MAX 3)
	G323	D./T. PROC.-DIALYSIS-HAEMODIALYSIS-ACUTE,REPEAT
	G330	D./T. PROC.-DIALYSIS-PERITONEAL-ACUTE (UP TO 48 HRS)
	G331	D./T. PROC.-DIALYSIS-PERITONEAL-REPEAT ACUTE (UP TO 48 HRS)
	G866	INTERMITTENT HEMODIAL AUX TREAT CTRE(PER TREAT)
	R849	D./T. PROC.-DIALYSIS-HEMO-INITIAL AND ACUTE

Codes for dialysis

type	code	Fee Code Description
FEECODE	Z569	ABDOMEN PERIT/OMEN-I&D.PELVIS ABSC. RECTAL VAGINAL APPROACH
	Z594	PERCUT.ABD.ABSCESS DRAINAGE INC.DAILY SUPERV'N
	Z595	ABDOMEN/PERIT/OMEN.REPLACE DRAIN CATHETER IN ABDO.ABSCESS

INCODE	1OT52DA	Drainage, abdominal cavity using endoscopic (laparoscopic) approach
	1OT52DATS	Drainage, abdominal cavity using endoscopic (laparoscopic) approach and leaving drainage tube in situ
	1OT52HA	Drainage, abdominal cavity using percutaneous (needle) approach
	1OT52HATS	Drainage, abdominal cavity using percutaneous (needle) approach and leaving drainage tube in situ
	1OT52HHD1	Drainage, abdominal cavity using percutaneous transcatheter approach and anti infective irrigating solution
	1OT52HHD2	Drainage, abdominal cavity using percutaneous transcatheter approach and salt irrigating solution
	1OT52HHD3	Drainage, abdominal cavity using percutaneous transcatheter approach and other irrigating solution
	1OT52LA	Drainage, abdominal cavity using open approach
	1OT52LATS	Drainage, abdominal cavity using open (incisional) approach and leaving drainage tube in situ
	1OT52MFQJ	Drainage, abdominal cavity using open approach with shunt terminating in circulatory system and pump NEC
	1OT52MFSJ	Drainage, abdominal cavity using open approach with shunt terminating in circulatory system [e.g. LeVeen Shunt, Denver Shunt]

Codes for percutaneous drainage

type	code	description
DX10CODE	T813	Disruption of operation wound, not elsewhere classified
	T814	Infection following a procedure, not elsewhere classified
	T8183	

INCODE	1OT52CQ	Drainage, abdominal cavity using per orifice [transvaginal] needle aspiration technique
	1OT52DA	Drainage, abdominal cavity using endoscopic (laparoscopic) approach
	1OT52DATS	Drainage, abdominal cavity using endoscopic (laparoscopic) approach and leaving drainage tube in situ
	1OT52HA	Drainage, abdominal cavity using percutaneous (needle) approach
	1OT52HATS	Drainage, abdominal cavity using percutaneous (needle) approach and leaving drainage tube in situ
	1OT52HHD1	Drainage, abdominal cavity using percutaneous transcatheter approach and anti infective irrigating solution
	1OT52HHD2	Drainage, abdominal cavity using percutaneous transcatheter approach and salt irrigating solution
	1OT52HHD3	Drainage, abdominal cavity using percutaneous transcatheter approach and other irrigating solution
	1OT52LA	Drainage, abdominal cavity using open approach
	1OT52LATS	Drainage, abdominal cavity using open (incisional) approach and leaving drainage tube in situ
	1OT52MFQJ	Drainage, abdominal cavity using open approach with shunt terminating in circulatory system and pump NEC
	1OT52MFSJ	Drainage, abdominal cavity using open approach with shunt terminating in circulatory system [e.g. LeVeen Shunt, Denver Shunt]

Codes for deep space infection

type	code	description
DX10CODE	K433	Parastomal hernia with obstruction, without gangrene
	K434	Parastomal hernia with gangrene
	K435	Parastomal hernia without obstruction or gangrene

Codes for parastomal hernia

type	code	Fee Code Description
DX10CODE	A410	Sepsis due to Staphylococcus aureus
	A411	Sepsis due to other specified staphylococcus
	A412	Sepsis due to unspecified staphylococcus
	A413	Sepsis due to Haemophilus influenzae
	A414	Sepsis due to anaerobes
	A4150	Sepsis due to Escherichia coli [E.coli]
	A4151	Sepsis due to Pseudomonas
	A4152	Sepsis due to Serratia
	A4158	Sepsis due to other Gram-negative organisms
	A4159	Gram-negative septicaemia, unspecified
	A4180	Sepsis due to Enterococcus
	A4188	Other specified sepsis
	A419	Sepsis, unspecified
	G450	Vertebro-basilar artery syndrome
	G451	Carotid artery syndrome (hemispheric)
	G452	Multiple and bilateral precerebral artery syndromes
	G453	Amaurosis fugax
	G454	Transient global amnesia
	G458	Other transient cerebral ischaemic attacks and related syndromes
	G459	Transient cerebral ischaemic attack, unspecified
	H341	Central retinal artery occlusion
	I210	Acute transmural myocardial infarction of anterior wall
	I211	Acute transmural myocardial infarction of inferior wall
	I212	Acute transmural myocardial infarction of other sites
	I213	Acute transmural myocardial infarction of unspecified site
	I214	Acute subendocardial myocardial infarction
	I2140	Acute subendocardial myocardial infarction of anterior wall
	I2141	Acute subendocardial myocardial infarction of inferior wall
	I2142	Acute subendocardial myocardial infarction of other sites
	I2149	Acute subendocardial myocardial infarction, unspecified site
	I219	Acute myocardial infarction, unspecified
	I220	Subsequent myocardial infarction of anterior wall
	I221	Subsequent myocardial infarction of inferior wall
	I228	Subsequent myocardial infarction of other sites
	I229	Subsequent myocardial infarction of unspecified site
	I230	Haemopericardium as current complication following acute myocardial infarction
	I231	Atrial septal defect as current complication following acute myocardial infarction
	I232	Ventricular septal defect as current complication following acute myocardial infarction
	I233	Rupture of cardiac wall without haemopericardium as current complication following acute myocardial infarction

	I234	Rupture of chordae tendineae as current complication following acute myocardial infarction
	I235	Rupture of papillary muscle as current complication following acute myocardial infarction
	I236	Thrombosis of atrium, auricular appendage, and ventricle as current complications following acute myocardial infarction
	I2380	Papillary muscle dysfunction as current complication following acute myocardial infarction
	I2381	Pericarditis as current complication following acute myocardial infarction
	I2382	Postmyocardial infarction angina as current complication following acute myocardial infarction
	I2388	Other current complications following acute myocardial infarction
	I2389	Current complications following acute myocardial infarction, unspecified
	I26	Pulmonary embolism
	I260	Pulmonary embolism with mention of acute cor pulmonale
	I269	Pulmonary embolism without mention of acute cor pulmonale
	I460	Cardiac arrest with successful resuscitation
	I461	Sudden cardiac death, so described
	I469	Cardiac arrest, unspecified
	I4800	Paroxysmal atrial fibrillation
	I4801	Persistent atrial fibrillation
	I481	Atrial flutter
	I483	Typical atrial flutter
	I484	Atypical atrial flutter
	I4890	Atrial fibrillation, unspecified
	I4891	Atrial flutter, unspecified
	I600	Subarachnoid haemorrhage from carotid siphon and bifurcation
	I601	Subarachnoid haemorrhage from middle cerebral artery
	I602	Subarachnoid haemorrhage from anterior communicating artery
	I603	Subarachnoid haemorrhage from posterior communicating artery
	I604	Subarachnoid haemorrhage from basilar artery
	I605	Subarachnoid haemorrhage from vertebral artery
	I606	Subarachnoid haemorrhage from other intracranial arteries
	I607	Subarachnoid haemorrhage from intracranial artery, unspecified
	I608	Other subarachnoid haemorrhage
	I609	Subarachnoid haemorrhage, unspecified
	I610	Intracerebral haemorrhage in hemisphere, subcortical
	I611	Intracerebral haemorrhage in hemisphere, cortical
	I612	Intracerebral haemorrhage in hemisphere, unspecified
	I613	Intracerebral haemorrhage in brain stem
	I614	Intracerebral haemorrhage in cerebellum
	I615	Intracerebral haemorrhage, intraventricular
	I616	Intracerebral haemorrhage, multiple localized
	I618	Other intracerebral haemorrhage
	I619	Intracerebral haemorrhage, unspecified
	I630	Cerebral infarction due to thrombosis of precerebral arteries
	I631	Cerebral infarction due to embolism of precerebral arteries
	I632	Cerebral infarction due to unspecified occlusion or stenosis of precerebral arteries
	I633	Cerebral infarction due to thrombosis of cerebral arteries
	I634	Cerebral infarction due to embolism of cerebral arteries
	I635	Cerebral infarction due to unspecified occlusion or stenosis of cerebral arteries
	I636	Cerebral infarction due to cerebral venous thrombosis, nonpyogenic
	I638	Other cerebral infarction

	I639	Cerebral infarction, unspecified
	I64	Stroke, not specified as haemorrhage or infarction
	I801	Phlebitis and thrombophlebitis of femoral vein
	I802	Phlebitis and thrombophlebitis of other deep vessels of lower extremities
	I803	Phlebitis and thrombophlebitis of lower extremities, unspecified
	I822	Embolism and thrombosis of vena cava
	I828	Embolism and thrombosis of other specified veins
	J120	Adenoviral pneumonia
	J121	Respiratory syncytial virus pneumonia
	J122	Parainfluenza virus pneumonia
	J123	Human metapneumovirus pneumonia
	J128	Other viral pneumonia
	J129	Viral pneumonia, unspecified
	J13	Pneumonia due to Streptococcus pneumoniae
	J14	Pneumonia due to Haemophilus influenzae
	J150	Pneumonia due to Klebsiella pneumoniae
	J151	Pneumonia due to Pseudomonas
	J152	Pneumonia due to Staphylococcus
	J153	Pneumonia due to Streptococcus, group B
	J154	Pneumonia due to other streptococci
	J155	Pneumonia due to Escherichia coli
	J156	Pneumonia due to other aerobic Gram-negative bacteria
	J157	Pneumonia due to Mycoplasma pneumoniae
	J158	Other bacterial pneumonia
	J159	Bacterial pneumonia, unspecified
	J160	Chlamydial pneumonia
	J168	Pneumonia due to other specified infectious organisms
	J170	Pneumonia in bacterial diseases classified elsewhere
	J171	Pneumonia in viral diseases classified elsewhere
	J172	Pneumonia in mycoses
	J173	Pneumonia in parasitic diseases
	J178	Pneumonia in other diseases classified elsewhere
	J180	Bronchopneumonia, unspecified
	J181	Lobar pneumonia, unspecified
	J182	Hypostatic pneumonia, unspecified
	J188	Other pneumonia, organism unspecified
	J189	Pneumonia, unspecified
	J690	Pneumonitis due to food and vomit
	J691	Pneumonitis due to oils and essences
	J698	Pneumonitis due to other solids and liquids
	N170	Acute renal failure with tubular necrosis
	N171	Acute renal failure with acute cortical necrosis
	N172	Acute renal failure with medullary necrosis
	N178	Other acute renal failure
	N179	Acute renal failure, unspecified
	O87102	Deep phlebothrombosis in the puerperium, delivered, with mention of postpartum complication
	O87104	Deep phlebothrombosis in the puerperium, postpartum condition or complication
	O87109	Deep phlebothrombosis in the puerperium, unspecified as to episode of care, or not applicable
	O87802	Other venous complications in the puerperium, delivered, with mention of postpartum complication

	O87804	Other venous complications in the puerperium, postpartum condition or complication
	O87809	Other venous complications in the puerperium, unspecified as to episode of care, or not applicable
	O87902	Venous complication in the puerperium, unspecified, delivered, with mention of postpartum complication
	O87904	Venous complication in the puerperium, unspecified, postpartum condition or complication
	O87909	Venous complication in the puerperium, unspecified, unspecified as to episode of care, or not applicable
	O88201	Obstetric blood-clot embolism, delivered, with or without mention of antepartum condition
	O88202	Obstetric blood-clot embolism, delivered, with mention of postpartum complication
	O88203	Obstetric blood-clot embolism, antepartum condition or complication
	O88204	Obstetric blood-clot embolism, postpartum condition or complication
	O88209	Obstetric blood-clot embolism, unspecified as to episode of care, or not applicable
	R092	Respiratory arrest
	R4020	Persistent vegetative state
	R4029	Coma, unspecified
	R570	Cardiogenic shock
	R571	Hypovolaemic shock
	R572	Septic shock
	R578	Other shock
	R579	Shock, unspecified
	R58	Haemorrhage, not elsewhere classified
	T810	Haemorrhage and haematoma complicating a procedure, not elsewhere classified

FEECODE	G082	CONT. VENOVENOUS HAEMODIAFILTRAT'N - INIT. & AC. (MAX 3)
	G083	CONT. VENOVENOUS HAEMODIALYSIS - INIT. & AC. (MAX 3)
	G085	CONT. VENOVENOUS HAEMOFILTRAT'N - INIT. & AC. (MAX 3)
	G090	VENOVENOUS SLOW CONT. ULTRAFILTRAT'N-INIT.& AC. (MAX 3)
	G093	Haemodiafiltration - Contin. Init & Acute (repeatx3)
	G095	Slow Continuous Ultra Filtration - Initial & Acute (repeat)
	G323	D./T. PROC.-DIALYSIS-HAEMODIALYSIS-ACUTE,REPEAT
	G391	D./T. PROC-OTHER RESUSCITATION-AFT 1ST 1/4HR.(PER 1/4HR).
	G395	D./T. PROC-OTHER RESUSCITATION-1ST 1/4HR. PER PHYS.
	G405	CRIT.CARE VENTIL.SUPPORT-INTENS.CARE-PHYS.IN CHGE-1ST DAY
	G406	CRIT.CARE VENT.SUPPORT INTENS.CARE PHYS IN CHGE 2ND TO 10DAY
	G521	D./T. PROC-LIFE THREAT.EMERG.SIT.-RESUSCITATION-1ST 1/4HR.
	G522	D/T PROC LIFE THREAT EMERG.SIT.RESUS.1/4HR AFT.1ST1/2 HR.
	G523	D./T.PROC.LIFE THREAT EMERG.SIT/RESUSC'N SECOND 1/4HR
	G557	D/T PROC.COMPREHEN.INTENS.CRIT.VENT.SUP.PHYS.IN CHGE-1STDAY
	G558	D/T PROC.COMP.INTENS.CRIT.VENT.PHYS.IN CHGE 2NDTO10THDAY
	G860	HOSPITAL HEMODIALYSIS
	G861	HOSPITAL PERITONEAL DIALYSIS
	G862	HOSPITAL SELF CARE OR SATELLITE HEMODIALYSIS
	G863	INDEPENDENT HEALTH CARE FACILITY HEMODIALYSIS
	G864	HOME PERITONEAL DIALYSIS
	G865	HOME HEMODIALYSIS

	G866	INTERMITTENT HEMODIAL AUX TREAT CTRE(PER TREAT)
	R849	D./T. PROC.-DIALYSIS-HEMO-INITIAL AND ACUTE

INCODE	1LZ19HHU1A	Transfusion, circulatory system NEC using autologous transfusion of red cell concentrates
	1LZ19HHU1J	Transfusion, circulatory system NEC using homologous transfusion of red cell concentrates
	1LZ19HHU2A	Transfusion, circulatory system NEC using autologous transfusion of plasma (fresh, frozen, stored)
	1LZ19HHU2J	Transfusion, circulatory system NEC using homologous transfusion of plasma (fresh, frozen, stored)
	1LZ19HHU4J	Transfusion, circulatory system NEC using homologous transfusion of platelets
	1LZ19HHU5J	Transfusion, circulatory system NEC using homologous transfusion of cryoprecipitate
	1LZ19HHU9A	Transfusion, circulatory system NEC using autologous transfusion of whole blood
	1LZ19HHU9J	Transfusion, circulatory system NEC using homologous transfusion of whole blood
	3GT20WC	Computerized tomography [CT], lung NEC with enhancement (contrast)
	3GT20WE	Computerized tomography [CT], lung NEC with and without enhancement (contrast)
	3GT70CA	Diagnostic nuclear (imaging) study, lung NEC using scintigraphy
	3GT70CC	Diagnostic nuclear (imaging) study, lung NEC using SPEC tomography (SPECT)
	3GT70CE	Diagnostic nuclear (imaging) study, lung NEC using PE tomography (PET)
	3GT70KC	Diagnostic nuclear (imaging) study, lung NEC using scintigraphy for perfusion study
	3GT70KD	Diagnostic nuclear (imaging) study, lung NEC using scintigraphy for ventilation study
	3GT70KE	Diagnostic nuclear (imaging) study, lung NEC using scintigraphy for perfusion and ventilation study
	3IM10VC	Xray, pulmonary artery following intravenous injection of contrast (with or without fluoroscopy)
	3IM10VX	Xray, pulmonary artery following intraarterial injection of contrast (with or without fluoroscopy)
	3IM10VY	Xray, pulmonary artery following intracardiac injection of contrast (with or without fluoroscopy)
	3IM12VA	Fluoroscopy, pulmonary artery without contrast
	3JY10VA	Xray, thoracic vessels NEC without contrast (with or without fluoroscopy
	3JY10VC	Xray, thoracic vessels NEC following intravenous injection of contrast (with or without fluoroscopy)
	3JY10VN	Xray, thoracic vessels NEC with fluoroscopy
	3JY10VX	Xray, thoracic vessels NEC following intraarterial injection of contrast (with or without fluoroscopy)
	3JY12VA	Fluoroscopy, thoracic vessels NEC without contrast
	3JY20WC	Computerized tomography, thoracic vessels NEC with enhancement (contrast)
	3JY20WE	Computerized tomography, thoracic vessels NEC with and without enhancement (contrast)
	3KR10VA	Xray, veins of leg NEC without contrast (with or without fluoroscopy)
	3KR10VC	Xray, veins of leg NEC following intravenous injection of contrast (with or without fluoroscopy)
	3KR10VN	Xray, veins of leg NEC with fluoroscopy
	3KR12VA	Fluoroscopy, veins of leg NEC without contrast
	3KX10VA	Xray, vein NEC without contrast (with or without fluoroscopy)
	3KX10VC	Xray, vein NEC following intravenous injection of contrast (with or without fluoroscopy)
	3KX10VN	Xray, vein NEC with fluoroscopy
	3KX10VX	Xray, vein NEC following intraarterial injection of contrast
	3KX12VA	Fluoroscopy, vein NEC without contrast
	3KX30DA	Ultrasound, vein NEC alone

	3KX30DB	Ultrasound, vein NEC with color flow
	3KX30DC	Ultrasound, vein NEC with Doppler
	3KX30DD	Ultrasound, vein NEC with color flow and Doppler

Codes for major complications

type	code	description
DX10CODE	K433	Parastomal hernia with obstruction, without gangrene
	K9145	Enterostomy malfunction, not elsewhere classified

INCODE	1NK52CA	Drainage, small intestine per orifice approach aspiration [or suction] technique
	1NK52CATS	Drainage, small intestine per orifice approach leaving drainage/decompression tube in situ

Codes for obstruction

type	code	Fee Code Description
FEECODE	R764	ARTERIES-EXPLORATION OF MAJOR ARTERY
	R905	LYMPHATIC-SPLEEN-EXC. SPLENECTOMY
	S149	INTESTINE-INC.-ENTEROTOMY-ILEOSTOMY
	S155	INTESTINE-INC-ENTEROTOMY-COLONOSCOPY WITH LAPAROTOMY.
	S157	INTESTINE-INC-ENTEROTOMY-COLOSTOMY.
	S158	INTESTINE-INC-ENTEROTOMY-CAECOSTOMY.
	S160	INTESTINE-INC-ENTEROTOMY-ENTERO-ENTEROSTOMY.
	S162	INTESTINE-EXC.-LOC.LESION OF INTESTINE.
	S165	INTESTINE-EXC-ANASTOMOSIS-SMALL INTESTINE-OTHER.
	S166	INTESTINE-EXC.-SML+LGE INTESTINE-TERM.ILEUM-CAECUM ASC.COLON
	S167	INTESTINE-EXC.-ANASTO.-LARGE INTESTINE -ANY PORTION.
	S168	INTESTINE-EXC.-ILEOSTOMY.SUBTOTAL COLECTOMY
	S169	INTESTINE-EXC-TOTAL COLECTOMY W/ILEO-RECTAL ANASTOMOSIS.
	S171	INTESTINE-EXC-LT.HEMICOLECTOMY WITH ANT.RESECT/ANAST. ETC.
	S173	INTESTINE-EXC.-ILEOSTOMY-2-SURGEON TEAM-ABDOMINAL
	S175	INTESTINE-OBSTRUCTION- NO RESECTION ONE STAGE
	S176	INTESTINE-OBSTRUCTION-+-ENTERO/ENTEROSTOMY ONE STAGE
	S177	INTESTINAL-OBSTRUCTION-ONE STAGE-WITH RESECTION
	S180	INTESTINE-OBSTRUCTION-WITH ENTEROTOMY.
	S181	INTESTINE-REP.-REVISION-ILEOSTOMY/COLOSTOMY-SKIN LEVEL.
	S182	INTESTINE-REP.-REVISION-ILEOSTOMY/COLOSTOMY-FULL THICKNESS.
	S184	INTESTINE-SUTURE OF INTESTINE
	S188	INTESTINE-EXC.-BOWEL RESECTION-WITHOUT ANASTOMOSIS.
	S213	RECTUM-EXC.-PROCTECTOMY-ANTERIOR RESECT./PROCTOSIGMOIDECTOMY
	S214	RECTUM-EXC.-PROCTECTOMY-ABDOMINO-PERINEAL RESEC/PULL THRU
	S215	RECTUM-EXC.PROCTECTOMY-2 SURG. TEAM ABDOMINAL SURGEON
	S216	RECTUM-EXC.-PROCTECTOMY-2 SURG. TEAM PERINEAL SURGEON

	S217	RECTUM-EXC.-PROCTECTOMY-HARTMANN PROC.
	S223	RECTUM-REPAIR-ANASTOMOSIS OF RECTUM
	S229	RECTUM-SUTURE-RECTUM,TRAUMA-EXTERNAL APPROACH.
	S231	RECTUM-SUTURE-CLOSURE OF FISTULA-RECTO VAGINAL
	S271	LIVER-EXCISION-EXTENDED RIGHT LOBECTOMY
	S312	ABDOMEN-INC-LAPAROTOMY WITH/WITHOUT BIOPSY
	S313	ABDOMEN-INC-PERITONEAL ABSCESS-SUBPHRENIC.
	S314	ABDOMEN-INC-PERITONEAL ABSCESS-ABDOMINAL.
	S340	ABDOMEN-REP-HERNIA-VENTRAL POST-OP.
	S343	ABDOMEN-SUTURE-SECONDARY CLOSURE FOR EVISCERATION
	S344	ABDOMEN-REPAIR-HERNIA-MASSIVE INCISIONAL

INCODE	1NM80LA	Repair, large intestine open approach using apposition technique [e.g. suturing, stapling]
	1NM80LAFH	Repair, large intestine open approach using biodegradable binding ring
	1NM80LAW2	Repair, large intestine open approach using collagen powder
	1NM80LAW3	Repair, large intestine open approach using fibrin glue
	1NM80LAXXE	Repair, large intestine open approach using local transposition flap [e.g. omental patch]
	1NQ87TF	Excision partial, rectum open abdominal approach [e.g. anterior] stoma formation with distal closure
	1OT35LAM0	Pharmacotherapy (local), abdominal cavity using open approach and antineoplastic agent
	2OT70LA	Inspection, abdominal cavity using open approach

Codes for re-operation

Mei (Lucy) Yang

CURRICULUM VITAE

Academic Background and Training:

Masters of Science *2017-2018*
Western University, Schulich School of Medicine and Dentistry

Post-medical education in General Surgery *2015-2020*
Department of Surgery
Western University, Schulich School of Medicine and Dentistry

Medical Degree *2011-2015*
Western University, Schulich School of Medicine and Dentistry
Class of 2015

Bachelors of Medical Science
2006-2010
Honours Specialization in Physiology
Western University

Publications:

1. Marolda CL, Li B, Lung M, **Yang M**, Hanuszkiewicz A, Rosale AR, Valvano MA. Membrane topology and identification of critical amino acid residues in the Wzx O-antigen translocase from Escherichia coli O157:H4. *J Bacteriol.* 192(23): 6160-71.
2. **Yang M,** Pepe D, Schlachta C, Alkhamesi N. Endoscopic tattoo: the importance and need for standardized guidelines and protocol. *JRSM*. DOI: 10.1177/0141076817712244
3. Alhassan N, **Yang M**, Wong-Chong N, Liberman AS, Charlebois P, Stein B, Fried GM, Lee L. Comparison between conventional colectomy & complete mesocolic excision for colon cancer – a systematic review and pooled analysis. *Surg endoscopy*. DOI:10.1007/s00464-018-6419-2
4. **Yang M.L.,** Ott M. (2018) Negative Pressure Wound Therapy to Decrease Surgical Nosocomial Events in Colorectal Resections. In: Recent Clinical Techniques, Results, and Research in Wounds. Springer, Cham. DOI: 10.1007/15695_2010_120
5. **Yang M**, Murphy PB, Allen L, Sela N, Govind S, Leslie K, Vogt K. Venous thromboembolism in emergency general surgery patients: a single center retrospective cohort study. Submitted Aug 2018 to Canadian Journal of Surgery
6. Sela N, Allen L, Murphy PB, **Yang M**, Patton P, Leslie K, Parry NG, Vogt KN. Obesity may not matter in emergency general surgery patients: an analysis of the association between body mass index and morbiditiy. Submitted Aug 2018 to The American Surgeon
7. **Yang M**, Wanis KN, Gilani O, Vogt K, Ott M, Van Koughnett JAM, Vinden C. The effect of peripherally acting mu opioid receptor antagonists (PAMORAs) on opioid induced bowel dysfunction: a systematic review and meta-analysis. Submitted to Colorectal Disease

Abstracts Presented (Presenter underlined):

Istl A, **Yang M**, Fleshner KA, Parker CE, Guizetti L, Singh S, Jairath V. Pre-operative biologic therapy is not associated with increased post-operative complications in inflammatory bowel disease patients undergoing elective surgery: systematic review and meta-analysis. Poster Presentation accepted Canadian Digestive Diseases Week 2019

Yang M, Wanis K, Gilani O, Ott M, Vogt K, Van Koughnett JA, Vinden C. The effect of peripherally acting mu opioid receptor antagonists on opioid induced bowel dysfunction: systematic review and meta-analysis. Canadian Surgery Forum 2018 ePoster Presentation

Alhassan N, **Yang M**, Wong-Chong N, Liberman AS, Charlebois P, Stein B, Fried GM, Lee L. Comparison between conventional colectomy and complete mesocolic excision for colon cancer – a systematic review and pooled analysis. World Congress of Endoscopic Surgery 2018 ePoster Presentation

Yang M, Murphy PB, Allen L, Sela N, Govind S, Vogt KN. Venous thromboembolism in emergency general surgery patients: a single centre retrospective study. Canadian Surgery Forum 2016 Poster Presentation

Sela N, Murphy PB, Allen L, **Yang M**, Patton P, Leslie K, Parry NG, Gray DK, Mele T, Leeper WR, Vogt KN. Obesity may not matter in emergency general surgery patients: an analysis of the association with body mass index and morbidity and mortality. Canadian Surgery Forum 2016 Podium Presentation

Awards & Grants

Four year continuing admission scholarship	*2006-2009*
PMA Dependents' Tuition Scholarship	*2009*
UWOSA Dependents' Tuition Scholarship	*2009*
Global Opportunities Award	*2011*
UWOSA Dependents' Tuition Scholarship	*2011*
Resident Research Grant $5000	*2017*

Academic Activities:

SAGES Advanced Upper GI Surgery course	*2018*
SAGES Advanced Colorectal Surgery course	*2018*
SWOSA conference	*2015*
Ontario Association of General Surgeons Conference	*2015, 2016, 2018*
Canadian Surgery Forum	*2016, 2018*
Professional Association of Residents of Ontario (PARO) General Council member	*2016-2018*
PARO Leadership Program	*2016-2018*
Resident Training Committee member	*2016-2019*
Postgraduate Medical Education Committee resident representative	*2016-2017*
Resident enhancement fund lead	*2017-2018*
Principles and practice of clinical research course	*2016*
Society of American Gastrointestinal and Endoscopic Surgeons member (SAGES)	*2016-2017*
SAGES basic laparoscopy and endoscopy surgery workshop	*2016*

Professional Memberships & Developments

Professional Memberships: CAGS, OAGS, ACS, OMA, CMA, CMPA, PARO, SAGES

Development: USMLE Step 2 CS, Surgical Foundations, LMCC part II, ATLS, ACLS, USMLE Step 2 CK, LMCC part I, USMLE Step 1, CPR